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(January to March.)

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THE STEAM LOCOMOTIVE

FIFTY YEARS AGO AND NOW.

READ SATURDAY, 13TH JANUARY, 1906,

BY

MR. SAMUEL RENDELL, M.I.MECH.E.,

MANCHESTER.

INTRODUCTION.

The Council of this Association has honoured me by the request to contribute a paper on the above subject. In accepting the invitation, I am conscious that although the field is special, it is also wide; so wide as to preclude any attempt to treat matters fully in the time at disposal.

I purpose, therefore, to limit the scope of this paper by confining it almost entirely to a discussion of main line engines from the Manchester standpoint. Perhaps the more correct title would be "Manchester Locomotives Fifty Years Ago and Now." After a brief notice of papers on the locomotive, previously contributed to this Association, there will be a review of the state of the locomotive industry in Manchester fifty years ago; followed by a comparison of passenger locomotives of that date with their descendants of the present day, on the following principal railways running express services into this city—namely, the London and North Western, Midland, Lancashire and Yorkshire, and Great Central.

This will lead to a consideration of the problem before locomotive engineers as influencing the general design of large modern locomotives; some of the engines on the above railways, and others built in Manchester for railways abroad, being used

in illustration, accompanied by a brief notice of the locomotive boiler and compounding, and closing with a query on the probable future of railway motive power.

PREVIOUS CONTRIBUTIONS TO THE SUBJECT.

On referring to back numbers of the Transactions, it will be seen that—except incidentally in the course of discussion—locomotive practice has occupied very little of our attention as an Association for some time past. Over ten years ago, on the 23rd of November, 1895, Mr. Edgar Worthington, now Secretary of the Institution of Mechanical Engineers, read a paper on "Electric Locomotives," the late Mr. T. Daniels, ex-President, occupying the chair; but it is necessary to refer back *more than seventeen years* to find a subject resembling the present.

On the 24th of November, 1888, one of our members, Mr. James Bolas, of Patricroft, read a paper on "Some Types of Modern Locomotive," which dealt chiefly with locomotives concerned in the race to the North on the East and West Coast routes; the late Mr. Samuel Dixon, then President, being in the chair. Going still further back, the locomotive is more in evidence, as indicated by the following papers, namely,—

1887.	"Locomotive Engines."	T. Ashbury.
1885.	"Locomotives."	T. Daniels.
1880.	"The Locomotive of 1879."	Do.
1872.	"The Locomotive Engine, Past and Present."	Do.
1868.	"Coal-burning Locomotives."	H. Johnson.

Besides these, in the period from 1865 to 1890, there were several papers on related subjects, such as locomotive axle bearings, tyre rolling mills, breakage of railway tyres, railway brakes (four papers), facing points and signals, automatic couplings, machine tools for railway carriage under-frames, the Manchester

and Liverpool Railway (two papers), and the life of George Stephenson.

It has been a custom with the Institution of Mechanical Engineers to review, every ten years, the progress of Marine Engineering; and these monographs, the last of which was read in 1901, have been very instructive and helpful. I would suggest that in future we do the same for the Locomotive. In the present instance we have to commemorate, not a decade, but a jubilee.

THE LOCOMOTIVE TRADE OF MANCHESTER FIFTY YEARS AGO.

Fifty years ago this very Saturday night, on the 14th of January, 1856, our Association was established, and holding its first meeting in the Merchant's Hotel, Oldham Street.

At that time the type of steam locomotive in such general use to-day had already been doing duty for more than a quarter of a century. In its manufacture Manchester was not behindhand. Mr. Thomas Ashbury has reminded us in his interesting paper on "The Jubilee of the Manchester Association of Engineers," that, "the first locomotive ever built in Manchester was constructed by Galloways in 1831 to the order of the Liverpool and Manchester Railway." That engine was appropriately named "Manchester," and it will be of further interest to note that its wheels had welded iron tyres, shrunk upon centres of wood, made by John Ashbury himself (uncle to our Mr. T. Ashbury), then a young man just out of his time, who afterwards founded the well-known "Ashbury's Works" at Openshaw.

The building of that first engine came about through Galloways being the repairing shop for the railway company, as they had no workshop of their own. The business was not extended beyond the delivery of four or five locomotives altogether, for the immense possibilities of the railway were not foreseen, and it was thought that about twenty engines would fulfil every

requirement, hence competition was not very keen to begin with, the price of a locomotive being fixed by the railway company at £900 to £1000.

It may, however, be remarked in passing, that although Galloways so early relinquished the construction of locomotives, the experience gained by them in locomotive boiler work designed for such a high pressure as 50 lbs. per square inch—the stationary boiler of that day only carrying from five to ten pounds—had a direct bearing on their subsequent career as boiler makers.

Fifty years ago Sharp, Stewart and Co., of the Atlas Works, Great Bridgewater Street, in this city, had long been far-famed for their locomotives. Originally makers of cotton machinery and machine tools, they had commenced to design and manufacture railway engines in 1834, guided by the inventive genius of Mr. Richard Roberts and the mechanical insight of Mr. Charles F. Beyer. Their first engine ran on the Liverpool and Manchester Railway. Three similar ones were supplied to the Dublin and Kingstown Railway—a line only five or six miles long—subsequently extended into the Dublin, Wicklow, and Wexford Railway. Fig. 1, Plate I., illustrates the "Hibernia," the first of the above engines for Ireland.

During the twenty years from 1834 to the end of 1855, Sharp, Stewart and Co. had turned out on an average forty-six engines per annum. In 1888 they removed from Manchester to the Atlas Works, Glasgow, and in 1903 became merged in the North British Locomotive Company.

William Fairbairn and Sons were building locomotives in 1856, and right up to their closing the works in Canal Street, off Great Ancoats Street, which occurred in 1868. The firm having absolutely stopped and there being no successors, the writer has been unable to obtain any account of their delivery.

Fig. 2, Plate I., shows the "Vulcan," an engine with inside cylinders, built by them in 1849 for the Shrewsbury and

Birmingham Railway, now part of the Great Western system. No doubt this engine would be in regular service in 1856.

Nasmyth, Wilson and Co., general engineers, of Patricroft—of steam hammer repute—entered the locomotive business in 1839, their first engine being for the London and Southampton, now London and South Western, Railway, and in the seventeen years from that date to the end of 1855, they had delivered an average of from six to seven engines per annum. The delivery fluctuated considerably, attaining a maximum in 1842 with seventeen engines, and dropping in 1843 to only one. According to their records, there was a gap from the end of 1853 (in which year five engines were delivered to the Great Northern Railway) to 1860, the inference being that no engines were built during that period.

Fig. 1, Plate II., has been reproduced from a drawing of a locomotive, constructed by them in 1847, which would be doing duty in 1856.

When this Association was holding its first meeting, Beyer, Peacock and Co. had quite recently commenced business right out in the country village of Gorton, the new shops being built on pasture land. As a contrast to Sharp's, in the midst of the crowded city, it may be mentioned that until 1882 a large plot of ground in the works' yard was laid out with flowers and shrubs, a gardener being one of the regular employees of the firm.

Beyer, Peacock and Co. turned out their first locomotive (for the Great Western Railway) in July, 1855, and at the close of the year their delivery amounted to twenty.

The following notes relating to railway companies' works in Manchester fifty years ago may prove interesting.

The Manchester, Sheffield, and Lincolnshire (now the Great Central) Railway Works—nicknamed "Gorton Tank"—had

been erected about 1846 by Mr. Richard Peacock, then Locomotive Superintendent.

It may here be remarked that it was due to the influence and business tact of Mr. Peacock, that the district of Gorton and Openshaw became transformed from meadows and corn fields into the great engineering centre which it now is. The copy (exhibited) of an old ordnance map of Gorton, drawn from a survey in 1845, will give some idea of the rural character of the neighbourhood before the ground was covered by the various great works and surrounding houses.

When Mr. Peacock left the M. S. & L. in 1854, to join Mr. Beyer, there was a period, probably covering 1856, during which the department was "farmed" by the Locomotive Superintendent, on a percentage of some kind, the result being that both rolling stock and shareholders were "starved."

Afterwards Mr. Charles Sacré acted in the dual capacity of Civil Engineer and Locomotive Superintendent to the Company, the Works (from 1859 to 1864) being under the management of Mr. S. W. Johnson, the well-known engineer, who has but recently resigned the position of Locomotive Superintendent to the Midland Railway Company.

From 1858 new engines were built yearly in the shops to replace obsolete and worn-out types, but such as were required for additional stock were let by contract to Fairbairn and Sons, or Beyer, Peacock and Co.

The London and North Western Railway Shops at Longsight were in charge of the afterwards celebrated Mr. John Ramsbottom, who in 1857 was transferred to Crewe as Locomotive Superintendent, in succession to Mr. Francis Trevithick. Only repairs were undertaken at Longsight, new engines being built at Crewe. Fig. 2, Plate II., shows Number 1876, an old class of engine having outside cylinders and six feet driving wheels, designed by Mr. F. Trevithick and built at Crewe in 1855.

The Midland Railway Company got into Manchester on the 1st of June, 1863, their trains then running on the M. S. and L. line from New Mills, *via* Guide Bridge, into London Road Station. The Belle Vue Running Sheds were opened in 1872, having been built on land bought for the purpose by Mr. Peacock. Fig. 3, Plate II., illustrates a class of tank engine, No. 201A, with inside cylinders, constructed by this company in 1855, rebuilt at Derby in 1870, and which is still in existence.

The Lancashire and Yorkshire Railway shops were at Miles Platting, the locomotive superintendent being Mr. W. Jenkins, who was also works manager. Theirs was the most active of the railway companies' works in Manchester. They had commenced to build engines in 1846, and their turn-out from then to the end of 1855 amounted to 89, of which 23 were constructed in the latter year. New works were laid out in 1886 at Horwich, to which the locomotive department was eventually removed.

In 1856 our railway works were engaged principally upon upkeep and repairs, and were not laid out for building new engines to anything like the extent they are now. To-day the majority of locomotives required for service in this country are both designed and constructed by the railway companies themselves, and private builders have to depend largely on orders from abroad. Take, for example, the companies already mentioned.

The Great Central Railway build a portion of their own engines at their works at Gorton, and order the remainder to drawings which they themselves supply; the London and North Western Railway have for a long time built all their own at their extensive works at Crewe; the Midland Railway, who have the largest number of locomotives running of any railway in Great Britain—namely, 2,790 at the end of June last—build

for themselves at Derby, but are occasionally forced to place orders out; and the Lancashire and Yorkshire Railway build all their own engines at their fine works at Horwich.

It may also be mentioned that the Great Central Company have in view the building of all the engines they require at their Gorton works. To accomplish this a very large piece of ground at Dukinfield has been cleared and levelled, on which new carriage and wagon shops are being erected, and in due course that department will be transferred from Gorton, leaving more room there for locomotive work.

According to returns made at the close of June, 1905, the numbers of locomotives in service upon the above railways were:—

Midland	2,790
North-Western	2,555*
Lancashire and Yorkshire	1,378
Great Central	623

The following comparative tables will give some idea of the progress of the locomotive industry in Manchester:—

TABLE I.

Name of Firm.	Commenced Building Locomotives.	Total number delivered to end of 1855.	Number of these for Abroad.
Galloways	1831	5†	—
Sharp, Stewart & Co.	1834	915	250
Wm. Fairbairn & Sons	No information	—	—
Nasmyth, Wilson & Co.	1839	109	2
Beyer, Peacock & Co.	1854	20	10
Totals		1,049	262

† Uncertain.

* The London and North-Western Railway had 500 duplicate engines at the close of June, 1905.

TABLE II.

Name o Firm.	Locomotives Delivered in 1855.		In 1905.	
	Total.	For Abroad.	Total.	For Abroad.
Sharp, Stewart & Co. ..	72	26	In Glasgow.	
Wm. Fairbairn & Sons..	No information.		Closed.	
Nasmyth, Wilson & Co..	None recorded.		45	42
Beyer, Peacock & Co. ..	20	10	119	106
Totals.....	92	36	164	148

It is worthy of note that the term "abroad" in the early years of our Association meant, generally, the continent of Europe. In these "colonial" days few engines are built in this country for European railways; the word "abroad" now relates principally to India, the British colonies in all parts of the world, Africa, South America, Japan, and China.

In making any comparison it should be borne in mind that the weight of material in an average-sized locomotive of to-day is very much greater, and that the accessories fitted to a modern engine are more numerous and more complex, than they were fifty years ago. If, in addition to the numbers of engines delivered, the total weights of material in them were given, there would be a better criterion.

We must, moreover, remember that fifty years ago the materials and machinery used in construction were very different from those employed to-day. Steel was not thought of as a general material for plates, castings, and forgings. Work was chiefly done by hand; there were few templets or jigs, and the standardization of parts, so common now, had not been commenced.

There were no hydraulic flanging or forging presses, or rivetters, no milling or grinding machines, no automatic lathes or

pneumatic tools, no twist drills, no high-speed steel, no electric cranes or electric light, no means of ascertaining the separate weights on the wheels of a locomotive; the drawing office had not heard of photo-prints, and the business was transacted without telephones or typewriters.

With regard to prices, the figure which had been offered by the railway company in 1829 for Stephenson's "Rocket" was £550, and, as previously stated, the company paid £900 to £1,000 for each of the four or five locomotives built by Galloways in 1831 and subsequently. Sharp's engine "Hibernia" (Fig. 1, Plate I.) with tender, built in 1834, cost the Dublin and Kingstown Railway Company £1,090.

All the early engines were experimental, and the prices very variable. Afterwards prices appear to have become somewhat more conformable to weight and type, and about 1855 a locomotive of moderate power, for that date, would sell for as much as from £2,500 to £3,000; but since then the improved processes of manufacture of both raw and finished materials have so cheapened the production, and competition, both at home and abroad, has so cut down the prices, that now a considerably heavier and more elaborate engine, with tender, can be bought for about the latter figure.

In common with other engineering productions, the price of a locomotive is governed by the design (whether straightforward or otherwise), the state of the material markets—in this case steel and copper more particularly—the labour market, and the keenness of competition, combined with conditions of delivery and payment, and whether for this country or abroad.

An enquiry often made is "How long will a locomotive last?" To this it is not easy to give any definite reply. Much depends upon the kind of material and workmanship put into it, whether it is suited to its duty, and how it is handled and cared for. Perhaps a good average life would be from twenty to twenty-five

years. Many last very much longer. The L. & N. W. engine "Waverley," for example, was built in 1863, and when Mr. Bolas read his paper twenty-five years later, in 1888, it was described as still doing first-class work.

The old M. R. Tank engine (Fig. 3, Plate II.) was built fifty years ago, and is not yet on the scrap heap. All the parts of a locomotive do not last equally long; ultimately it beomes a matter of rebuilding with, say, a new boiler and numerous details, and it is then a question for consideration whether the old class is to be perpetuated, or scrapped. The higher pressures and heavier duties of modern times are not in favour of longevity.

THE LOCOMOTIVE OF 1855 AND 1905.

Our President, in his inaugural address, summed up the progress of the locomotive during the past fifty years in few words when he said "the design is still the same, excepting for its increased dimensions and working pressures." His remark may be applied with practically equal force to a comparison of the modern "iron-horse" with its ancestor the "Rocket" of *seventy-five* years ago.

Not that the "Rocket" was the first railway engine by any means, for Richard Trevithick constructed one which ran upon a line from Pen-y-darren Works into Merthyr Tydvil, a distance of nine miles, more than a century ago; in fact, the "Rocket" itself was the *nineteenth* locomotive turned out from Stephenson's Works at Newcastle.*

George Stephenson and his son Robert were not the *inventors* of the locomotive, nor of those devices which made it a success, although the "Rocket," built by them, conclusively demonstrated the advantage of that type of engine for fast running with passenger trains.

* George Robert Stephenson, a nephew of George Stephenson, who was present as a boy at the historical Rainhill trials in 1829, when the "Rocket" won the prize, and in after life was for many years head of the establishment of Robert Stephenson & Co., Newcastle-on-Tyne, passed away only last October, aged 86.

It has been well said by Zerah Colburn, writing of George Stephenson, that "it no more detracts from his acknowledged sagacity and skill as an engineer, or his singular worth as a man, that he did not 'invent' the Locomotive Engine, than it is a reproach to Sir Isaac Newton that he did not originate the electric telegraph. The inventive faculty, indeed, is only rarely found united with that tenacity of purpose, determined energy, and worldly thrift which distinguished the famous north country engineer."

Stephenson's "Rocket" was not in itself an invention, but a remarkably neat and successful design, embodying in its arrangement such of the inventions of others as gave it a promise and potency beyond the dreams of the early railway men.

In it there existed without superfluity the main essentials of its modern descendant, such as a multitubular boiler, high pressure steam, exhaust blast pipe, bearing springs, a pair of cylinders driving the wheels through a simple connecting rod and crank, and plain flanged wheels running on a plain rail, the tractive effort being due to the adhesive weight alone.

It will be observed that in the "Hibernia," Fig. 1, Plate I, which was Sharp's first design of locomotive, there was a departure from the "Rocket" type in the employment of a vertical cylinder and bell-crank. This arose from a fear that an inclined or horizontal cylinder would not be satisfactory, owing to the wear produced by the weight of the piston. Galloways' engine of 1831, and others among the early locomotives, had also vertical cylinders, but the arrangement was only short-lived.

The persistency of the "Rocket" type of locomotive engine is nothing short of phenomenal in view of the radical changes that have taken place in both stationary and marine steam engines in the same time.

The evolution of the locomotive during the past fifty, or even seventy-five, years, has been confined to *growth* in "dimensions

and working pressures," so greatly increasing its weight, hauling capacity, and speed, that if Stephenson could return to the footplate of a modern main line engine, he would open his eyes in amazement.

To illustrate this growth and the consequent alteration in general appearance, I have prepared the accompanying outline diagrams, to the same scale, of the various passenger locomotive engines enumerated below.

LONDON & NORTH-WESTERN RAILWAY COMPANY.

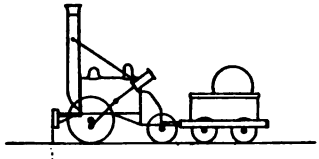

Fig. 1. The "Rocket" of 1829.*

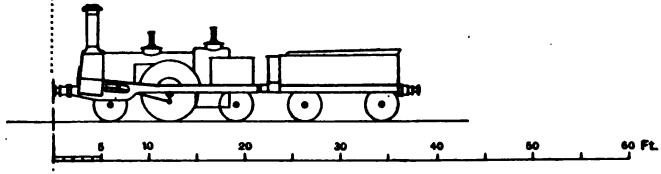

Fig. 2. The "6ft. Old Crewe Class," No. 1876, of 1855 (see Fig. 2, Plate II.).

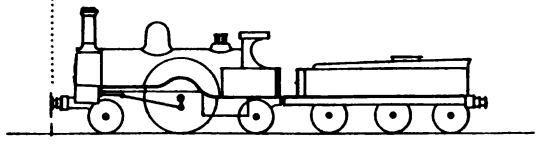

Fig. 3. Mr. Ramsbottom's "Waverley," of 1863, illustrated in Mr. Bolas's paper of 1888.

* The "Rocket" is preserved in South Kensington Museum, but there is some doubt as to the appearance it presented in 1829, owing to several subsequent alterations.

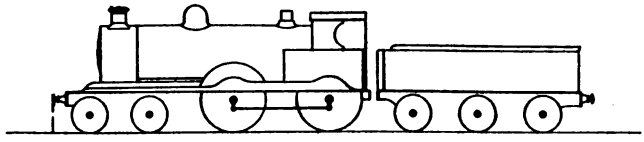

Fig. 4. Mr. Whale's "Precursor," May, 1905, the first of the latest class of L. & N. W. Passenger Engines (see Fig. 4, Plate II.).

NOTE.—The "Rocket" is included, having been in service on what ultimately became a part of the L. & N. W. system.

MIDLAND RAILWAY COMPANY.

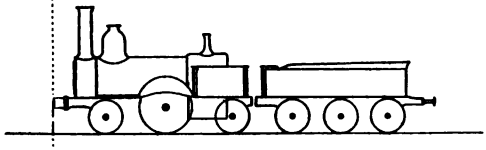

Fig. 5. Sharp, Stewart and Co.'s (then Sharp Brothers) "Jenny Sharp," built for the M. R. in 1847, and doubtless doing excellent work in 1855. Engines similar, but slightly larger, were delivered in 1853, of which sufficient particulars are not at hand to enable a sketch to be made.

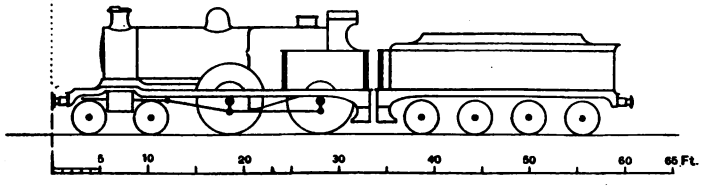

Fig. 6. Mr. Johnson's Three-cylinder Compound Express, No. 2,632, of 1902, one of the latest class of M. R. Passenger Engines (see Fig. 5, Plate II.).

LANCASHIRE & YORKSHIRE RAILWAY COMPANY.

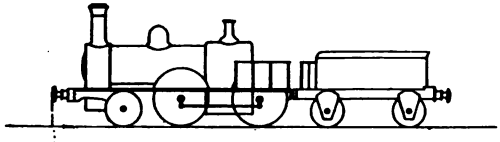

Fig. 7. Passenger Engine by the L. & Y. R., built and in service in 1855.

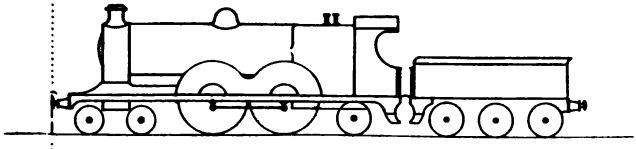

Fig. 8. Mr. Aspinall's Ten-wheeled Express, "Atlantic" type, No. 1,406, of 1902, one of the latest class of L. & Y. Passenger Engines (see Fig. 6, Plate II.).

GREAT CENTRAL RAILWAY COMPANY.

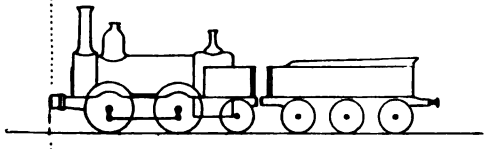

Fig. 9. Sharp, Stewart & Co.'s Engine, built for the M. S. & L. Railway in 1847, and in service in 1855. The tender is approximate only, nothing further being known than that it contained 1,000 gallons and ran on six wheels.

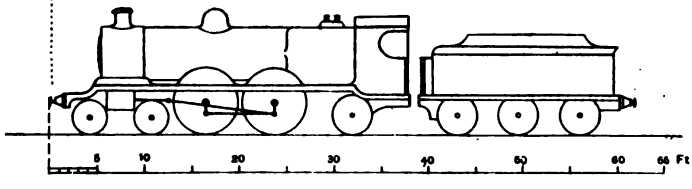

Fig. 10. Mr. Robinson's "Atlantic" type Express, No. 266, built by Beyer, Peacock and Co. in 1904, one of the latest class of G. C. Passenger Engines (see Fig. 1, Plate III.).

Outlines are also given, to the same scale as those above, of two recent huge American locomotives, for the ordinary gauge of 4ft. 8½in. between rails, both of which were exhibited at the St. Louis Exhibition of 1904.

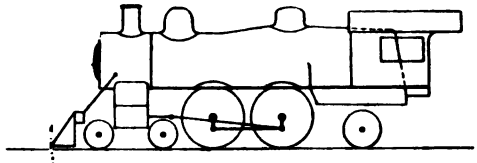

Fig. 11 is an "Atlantic" type Engine, Company's No. 1,017, being one of an order for twenty, built at the Rogers Locomotive Works for the Illinois Central Railroad. Detailed particulars of the tender are not at hand.

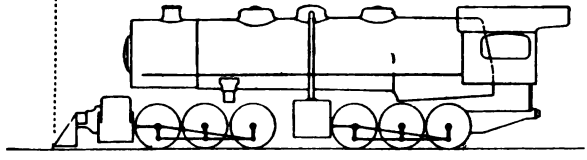

Fig. 12 is a Mallet compound articulated locomotive, Company's No. 2,400, a type not common in the States, built at the Schenectady Locomotive Works for the Baltimore and Ohio Railroad. Unlike the passenger engines above, this conforms to the heavy goods type, having been constructed for hill-climbing on the Company's section over the Alleghany Mountains. For want of sufficient space the tender, built by the Railroad Company, is omitted.

The latter engine has been added by request, and both are interesting as having been seen at the Exhibition by several of our members. More detailed descriptions will be found in *Engineering* for 1904, the number for August 5th containing the

Mallet compound and that for December 2nd the "Atlantic" type.

Table III gives the leading particulars of the twelve locomotives just referred to, and, leaving out the "Rocket" and the big American machines, it clearly indicates how the dimensions of passenger engines in common use on the four railways named have increased during the past fifty years from (say) cylinders of 16ins. diameter and heating surface of 900 sq. ft., to cylinders of 19in. diameter and heating surface of 2,000 sq. ft., the pressures at the same time rising from 100 to 180lbs. per square inch, and the weights loaded (without tender) from 23 to 60 tons.

The types of engines are expressed in the Table, so far as wheel arrangement is concerned, by a system of notation which is now often used in this country and America. For all ordinary types three figures suffice, the first and last of which represent the number of bogie or carrying wheels at the leading end and at the trailing end respectively; if none, the statement is made definite by the use of a 0. The middle figure indicates the number of driving or coupled wheels. The "Waverley," for example, is a "single-driver," with a pair of leading carrying wheels and a pair of trailing carrying wheels. It is therefore represented by 2—2—2.

The "Precursor" and the Midland Compound have each four coupled wheels, with a four-wheeled leading truck or bogie, and no carrying wheels in the rear; they are known as 4—4—0. The L. & Y., G. C., and American "Atlantic" types have four coupled wheels, four wheeled leading bogie, and two trailing carrying wheels; they are 4—4—2. The American Compound has two groups of six coupled wheels, and no carrying wheels either leading or trailing; four figures are required to express this, namely, 0—6—6—0.

The letters over the numerals indicate whether the cylinders are outside (outs.), or inside (ins.), or compound (comp.); in the

TABLE III.—Leading particulars of the "Rocket," the "Waverley," and locomotives in service in 1855 and 1905.

Railway.	Engine.				Designer.	Type.	Cylinders.		Driving Wheels.		Working Pressure.	Grate Area.	Heating Surface.			Tender.		Weights Loaded.		
	Fig.	No.	Name,	Date.			Diam.	Stroke.	Dia.				Tubes.	Firebox	Total.	Water.	Coal.	Engine.	Tender.	Total.
							In.	In.	Ft.	In.	lb. sq.in.	Sq. ft.	Sq. ft.	Sq. ft.	Sq. ft.	Galls.	T.	Tons Cwt	Tons Cwt	Tons Cwt
Liverpool & Manchester	1	..	Rocket...	1829	Stephenson.....	Outs 0-2-2	8	16½	4	8½	50	6	118	20	138	Abt 250	..	4 5	3 4	7 9
L. & N. W.	2	1876	Old Crewe Class	1855	F. Trevithick...	Outs 2-2-2	15¼	20	6	0	120	13·8	765	85	850	1500	..	20 8	17 8	37 16
Do.	3	..	Waverley	1863	J. Ramsbottom	Outs 2-2-2	17	24	7	7½	120	15	1013	85	1098	1500	2	27 0	18 8	45 8
Do.	4	513	Precursor	1905	G. Whale.....	Ins 4-4-0	19	26	6	*9	175	22·4	1849	161	2010	3000	6	59 15	37 0	96 15
M. R.	5	..	Jenny Sharp	1847	Sharp Brothers	Ins 2-2-2	16	20	5	6	80	Approx. 11	847	72	919	800	1½	21 9	13 1	34 10
Do.	6	2632	...	1902	S. W. Johnson	3 Comp 4-4-0	One 19 Two 21	26	7	0	195	26	1448	150	1598	4500	..	59 10	52 13	112 3
L. & Y.....	7	..	...	1855	W. Jenkins.....	Ins 2-4-0	15	22	5	9	Probably 100	14	827	86	913	1204	2¼	27 13	16 7	44 0
Do.	8	1406	...	1902	J. A. F. Aspinall	Ins 4-4-2	19	26	7	3	175	26	1877	176	2053	2290	5	58 15	30 13	89 8
G. C.....	9	..	...	1847	Sharp Brothers	Ins 0-4-2	16	22	5	0	Probably 100	11·4	791	68	859	1000	..	24 0	Approx. 16 0	40 0
Do.	10	266	...	1904	J. G. Robinson	Outs 4-4-2	19½	26	6	9	180	26	1778	153	1931	4000	.	67 12	44 3	111 15
American I. C. R. R.	11	1017	...	1904	Rogers Loco Works	Outs 4-4-2	20	28	6	7	200	50·7	3052	180	3232	5830 Engl.	14	83 16	65 10	149 6
American B. & O. R.R.	12	2400	...	1904	Schenectady Loco Works	4 Comp 0-6-6-0	Two 20 Two 32	32	4	8	235	72·2	5380	220	5600	5830 Engl.	12	144 5	64 0	208 5

* With New 3in. Tyre.

NOTE.—The heating surfaces are such large and (to some extent) indefinite quantities that decimal places are omitted as superfluous.

last case the number of cylinders is stated as, "3-comp." or "4-comp."

The capacities of the two American tenders are given in English or Imperial gallons of 277 cubic inches, or 10-lbs. of water. The gallon still used in the United States is the old British or "Winchester" wine gallon of 231-cubic inches, or $8\frac{1}{3}$-lbs. of water. The capacity of each of these tenders is 7,000 U.S., or 5,830 English, gallons.

In Table IV. I have worked out for each engine the tractive effort, and the relative proportions of boiler surfaces to one another and to the cylinders; taking the area of one cylinder only, as perhaps the fairest basis, seeing that, owing to the cut-off, the two cylinders are practically alternately fed with steam from the boiler; and neglecting the stroke, because a longer stroke is generally regarded, not as put in to draw more steam from the boiler, but rather to increase the expansion.

The tractive efforts have been calculated from the usual formula $t = \frac{d^2 s}{w}$, where d = diam. of cylinder, s = stroke, and w = diam. of driving wheel, all in inches. A mean effective pressure (M.E.P.), at starting, of 75% the working boiler pressure, has been adopted. Many engineers, especially in America, rely upon getting as much as 80 or 85%, which the writer considers rather high. With regard to the tractive efforts of the compound engines something will be said later on.

The term "tractive *effort*" is used in preference to the more common "tractive *power*," as being in line with modern mechanical science, where "effort" signifies a simple pull or push, and "power" involves in addition, the ideas of space and time. The total T.E. has been expressed in cwts., as being more convenient than pounds.

Neglecting for the moment, the "Rocket" and the American engines, the Table shows that the passenger locomotives now in

TABLE IV.—Tractive Efforts and Boiler Proportions of Locomotives in Table III.

Railway.	Fig.	Name or Number.	Date.	Type.	Tractive Effort at Rail in lbs. per lb. M.E.P. in Cylinders.	75% of Working Boiler Pressure in lbs. per sq. in.	Total Tractive Effort in cwts. at a M.E.P. = 75% Working Pressure.	Sq. ft. of Tube Surface per sq. ft. of Firebox Surface.	Sq. ft. of Total Heating Surface per sq. ft. of Firegrate.	Cylinder Area in sq. ins.	Sq. ft. of Total Heating Surface per sq. in. of Cylinder.	Sq. ft. of Grate Area per sq. in. of Cylinder.
Liverpool & Manchester	1	"Rocket"	1829	Outs. 0—2—2	18·7	37·5	6·2	5·9	23·0	50·2	2·7	·12
L. & N. W.	2	1876	1855	Outs. 2—2—2	64·6	90·0	52·0	9·0	61·6	182·6	4·6	·07
Do.	3	"Waverley"	1863	Outs. 2—2—2	75·8	90·0	60·9	11·9	73·2	226·9	4·8	·06
Do.	4	"Precursor"	1905	Ins. 4—4—0	115·8	131·25	135·7	11·5	89·7	283·5	7·1	·08
M. R.	5	"Jenny Sharp"	1847	Ins. 2—2—2	77·5	60·0	41·5	11·7	83·5	201·0	4·5	·05
Do.	6	2632	1902	3 Comp. 4—4—0	Equivalent 89·3	146·25	116·6	9·6	61·4	(19in. dia.) 283·5	5·6	·09
L. & Y.	7	—	1855	Ins. 2—4—0	71·7	75·0	48·0	9·6	65·2	176·7	5·1	·08
Do.	8	1406	1902	Ins. 4—4—2	107·8	131·25	126·3	10·6	79·0	283·5	7·2	·09
G. C.	9	—	1847	Ins. 0—4—2	93·8	75·0	62·7	11·6	75·3	201·0	4·2	05
Do.	10	266	1904	Outs. 4—4—2	122·0	135·0	147·0	11·6	74·2	298·6	6·4	·08
American I. C. RR.	11	1017	1904	Outs. 4—4—2	141·7	150·0	189·7	16·9	63·7	314·1	10·2	·16
American B. & O. RR.	12	2400	1904	4 Comp. 0—6—6—0	Equivalent 182·8	176·25	287·6	24·4	77·5	(2-20in. dia.) 628·2	8·9	·11

use on the four railways named, exert tractive efforts two and a half times as great as those of fifty years ago; in other words, a pull of, say, two and a half tons, has been increased to six and a half tons.

The latest L. & N. W. engine, the "Precursor," is seen to be equal, in hauling capacity, to twenty-two "Rockets," and the gigantic American Compound, to forty-six, all upon the same gauge of rails.

Confining our attention again to the English locomotives of fifty years ago and to-day, it will be observed that, allowing for exigencies of design, the boiler proportions have remained fairly uniform, roughly confirming the old rules which allowed about ten square feet of tube surface to one square foot of firebox, about sixty square feet of total heating surface to one square foot of firegrate, and about five square feet of total heating surface to one square inch of piston area.

In the case of the "Rocket" the grate area was proportionately large and the tube surface small. This latter was due to the boiler barrel being only six feet long, with but twenty-five tubes of 3 inches diameter, modern practice in this country putting more tubes into the same space, by making them from one and three-quarter to 2 inches diameter. But things were then in an experimental stage, and settled proportions had not been arrived at.

The American Engines, on the other hand, while (owing to the poor coal they burn) possessing grates as large in proportion to the cylinders as the "Rocket," have enormous tube heating surfaces, proportionately much greater than anything else in the Table.

In this respect the modern American locomotives are, as a rule, far in excess of those on British and Continental railways. It is, indeed, questionable whether they are not overdone, and common report puts them down as un-economical machines, but we must remember that the conditions of railway working on the other side of the Atlantic are very different from those that

obtain here; moreover, in designing such overgrown constructions it is not always possible to maintain any recognized proportions. American railroads are blessed with more ample limits in height and width than are ours. On this account similar engines could not be put upon an English road.

THE PROBLEM BEFORE LOCOMOTIVE ENGINEERS.

Of late years the problem before locomotive engineers has been how to increase the hauling capacity and speed of their engines. The traffic has increased, both in passengers and goods, and such additional provision has been made for the accommodation and comfort of passengers that the weights of these trains are now much greater in proportion to the numbers they carry than they were even a few years ago. The question naturally arises, "Has anything been done to ease the running of the load?"

It may be instructive to consider this question in detail.

Since D. K. Clark's experiments, the results of which were published in his "Railway Machinery" in 1855, something has been done to diminish the train resistance per ton of load by improved designs of axleboxes, with oil lubrication instead of railway grease, thereby reducing the axle friction from about six lbs. per ton to between three and four lbs., at slow speed, the resistance rising as the speed increases; and some companies are trying roller bearings on their coaches, the result being still more favourable, with the additional advantage of very little perceptible wear.

It may be noted in passing that so far as the wheels themselves are concerned, no doubt the *rolling* friction has been reduced in the last fifty years, by the general use of steel for tyres and rails, much harder and more durable than the iron of which they used to be made; but this can only be a small item.

The reduction of axle friction is quite in the right direction, and would be most effective, if railways were as a rule of such a

"first-class" nature as to be absolutely level and straight, a condition approximated to in a few countries only, as, for example, the Netherlands. Generally speaking, on any railway in our own island, gradients, though not in many instances severe, are frequent, and curves are numerous.

The locomotive is required to haul its train through all these, in all kinds of weather, to its destination, and keep scheduled time, with perhaps the assistance of a pilot engine on a specially steep bank, the tendency being to discard even this. In addition to overcoming axle friction there must therefore be power enough to lift the load up the stiffest incline and drag it round the sharpest curve, the two sometimes occurring in combination.

The effect of gravity against ascending an incline is strictly = load × sine of angle, but as the angle is small, the sine is practically equal to the gradient. For a gradient of 1 in 100, or $\frac{1}{100}$, the resistance due to gravity is $\frac{2,240}{100}$ = 22·4lbs. per ton. For $\frac{1}{50}$ it is $\frac{2,240}{50}$ = 44·8lbs. per ton, and so on. It is at once evident that, in comparison with axle friction, we have here something more formidable, and which *does not admit of reduction.*

When a train runs through a curve, especially if it be a reverse, or S, curve, a large amount of resistance arises through slip, the wheel flanges grinding against the inside edges of the rails, and the collars of the axle journals being forced over against the ends of the bearings, thus developing end friction.

Curve resistance depends upon the radius of the curve and the length of rigid wheel-base of the vehicles. It is a rather uncertain quantity, varying also with the wind, and with the state of the rails, whether dry or greasy. For example, with vehicles of 12ft. rigid wheel-base, on a curve of 1,500ft. radius, it will probably be from 1½ to 3½lbs. per ton; on a 1,000ft. curve, from 2 to 5lbs. per ton. With a shorter wheel-base the resistance will be somewhat less.

During the latter half of the past half-century, curve friction has been reduced by making better arrangements for end wear, and by ampler lubrication. Much has also been accomplished by the more general adoption of bogies. A vehicle with a long rigid wheel-base is very unsuitable for working over sharp curves, because the wheel flanges meet the rails at an angle, not only "grinding" badly, with consequent flange wear, but also tending to "mount" and leave the track.

For this reason, on modern rolling stock, short-based bogies, although heavier and more expensive than fixed axles, are used for long vehicles. A bogie is free to set itself on the rails, thus materially diminishing the curve resistance. Two bogies, each having either two or three axles, will carry a very long and heavy vehicle.

The atmosphere tells against high speed, and wind has great effect in increasing train resistance. A head wind virtually increases the rate at which the train is rushing through the air. A wind not dead in front, but inclined to one side, is still more detrimental, in that it produces the additional effect of forcing the vehicles to one side, causing an action similar to that on a curve. The wedge-shaped projections, or "wind-cutters," seen on some Continental locomotives, are probably of little use.

Among other things that may militate against high speed are badly-balanced wheels and the fan-action of wheel spokes. In this respect the passenger coaches of to-day, with their carefully-balanced built-up wooden disc wheels, are an improvement on those of fifty years ago.

A further cause of retardation, not often noticed, is, that in rounding a curve, the wheels are like so many gyroscopes, each endeavouring to keep to its own plane of rotation, and producing an increased pressure between the curved rail and the wheel flange, thus entailing the absorption of additional power when running at high speed.

To sum up, it appears that in the past fifty years there has been some reduction in such train resistances as are due, chiefly, to axle and curve friction, the resistance due to gradient remaining unalterable; but, in the meantime, the loads to be hauled have increased out of all proportion, and competition has been keen between the various companies in the direction of increased speed for passenger trains, longer non-stop journeys, and accelerated goods services.

Increased hauling capacity and speed may be obtained by means of larger cylinders, higher pressure, and more boiler power. For the maintenance of speed this last item is very important. The boiler may be called the lungs of the locomotive, and we all know that to run a race lung power is essential. Some little consideration is necessary to determine the size of driving wheels most suitable to the duty to be performed, for whilst small wheels give greater traction and less speed, large wheels give less traction and greater speed, the former being therefore more suitable for goods and the latter for passenger traffic; in any case the adhesion weight must be sufficient to absorb the tractive effort at the tread of the driving wheels.

The past half-century has seen a great increase in axle loads, owing to the use of heavy steel rails. As stated in Mr. Ashbury's paper (previously referred to), the first Bessemer steel experiments were made at Galloway's Knott Mill Iron Works in 1856, and the writer is informed that the first Bessemer steel rails were rolled from some ingots of this steel at the Pendleton Iron Works, and laid on the Manchester and Bolton section of the Lancashire and Yorkshire Railway, where they did good service for many years. It was, however, a long time before the old iron rails were generally replaced by steel, mainly because of the high price of the latter in those early days.

The maximum safe axle load in tons on a steel rail of ordinary section may be simply obtained by dividing the weight of rail in

pounds per yard by five. Thus, a 60lb rail should be good for 12 tons per axle, an 80lb. rail for 16 tons, and a 100lb. rail for 20 tons.

With "single" engines—that is, locomotives having but a single pair of driving wheels, usually of large diameter, the adhesion weight, with 100lb. rails, is therefore limited to 19 or 20 tons. Slipping is not uncommon at starting, even with steam sanding apparatus, and great hauling capacity is impossible. For this reason these engines, usually of fine appearance, and still in evidence on the L. & N. W., Midland, and G. C. for light passenger work, have given place to those having two axles, or four wheels, coupled; while in some cases six wheels coupled are in use for heavy passenger trains, and goods engines have now invariably either six or eight wheels coupled.

Fifty years ago a very large driving wheel was looked upon as a necessity for high speed. The general tendency now is to rely more on an increased number of revolutions per minute than upon unusually big wheels.

The difficulties, mentioned in Mr. Bolas's paper, and long familiar to locomotive builders, in the way of putting a fair-sized engine upon a narrow-gauge railway, are now fast beginning to appear in ordinary 4ft. 8½in. gauge work, with this difference, that on the ordinary gauge the difficulties are accentuated by the fact that the space allowed outside the rails is less in proportion than for narrow gauges.

Large cylinders (*i.e.*, larger than those at present in use) are not easily got inside, because of the limited space between the frames, and may not be possible outside, because foul of station platforms, bridges, and tunnels. Large boilers require large grates, and consequently long fireboxes, and often, after the boiler centre has been pitched at such a height that the chimney must be made ridiculously short to avoid being knocked off by bridges and tunnels, there is still trouble in getting a satisfactory firebox and ashpan, clear of the axles and wheels which are underneath and on each side of them.

LOCOMOTIVES ON MANCHESTER RAILWAYS.

Of the modern simple passenger locomotives already noticed the L. & N. W. "Precursor" (Fig. 4, Plate II.) is a plain, straightforward engine, having inside cylinders with balanced slide valves on top, actuated by Joy's radial valve gear.

The L. & Y. engine (Fig. 6, Plate II.) has inside cylinders of the same size as the "Precursor," with top valves and Joy's gear, but driving wheels of six inches larger diameter. The peculiarity of this engine is that it is of the 4—4—2, or "Atlantic" type, a name due to the circumstance that the first engines of this type to receive marked attention ran express trains to Atlantic City, the American Blackpool.

The first put into service in this country was designed and built by Mr. H. A. Ivatt, Locomotive Engineer of the Great Northern Railway, in 1898. Soon after Mr. J. A. F. Aspinall, then Chief Mechanical Engineer, now General Manager, of the L. & Y. Ry., turned out a number of "Atlantics." The first of these was put in traffic in February, 1899. That under notice is dated 1902. The special feature of the type is that the coupled axles are all in front of the firebox, the weight of which is partly carried by a small wheel under it, leaving room to make it of ample size. This wheel arrangement is fast gaining ground, and bids fair to replace the ordinary four-wheel coupled engine for express traffic.

Mr. Robinson's Great Central engine (Fig. 1, Plate III.) is also an "Atlantic," having outside cylinders connected to the second coupled axle, thus differing from the L. & Y., which has inside cylinders connected to the first coupled axle. The cylinders are cast thick enough to bore out to 20in. diameter, but so far they have not been increased beyond 19½in. Two engines were built in 1903, similar in all respects, except that the small trailing wheel was replaced by another coupled wheel, making the type 4—6—0, and having the disadvantage that the firebox had to be reduced in depth to clear the hind coupled axle. A photograph of this engine is exhibited.

Plate III. also illustrates the latest type of goods engine on each of the four railways. Table V. gives the leading particulars, and Table VI. the proportions worked out as in Table IV., with which it will be seen they agree fairly well.

TABLE V.—Leading particulars of some English Goods Locomotives, &c.

Railway.	Plate and Fig.	Type.	Cylinders. Dia.	Cylinders. Stroke	Driving Wheels. Dia.	Working Pressure.	Grate Area	Heating Surface. Tubes	Heating Surface. Fire-box.	Heating Surface. Total.	Tender. Water	Tender. Coal.	Weight Loaded. Engine.	Weight Loaded. Tender.	Weight Loaded. Total.
			In.	In	Ft. In.	lbs sq in	Sq. ft.	Sq. ft.	Sq. ft.	Sq. ft.	Galls	Tons.	T. C.	T. C.	T. C.
L. & N. W..	III. 2	4 Comp. 4-6-0	2·15 2·20½	24	5 3 With 3in. Tyres.	200	20·5	1630	123	1753	2500	5	60 0	31 12	91 12
Midland ..	III. 3	Ins. 0-6-0	18	26	5 3	175	21·1	1303	125	1428	3500	..	43 16	37 4	81 0
L. & Y.....	III. 4	Ins. 0-8-0	20	26	4 6	180 *	26 26	1877 1775	162 125	2039 1900	3600	5	53 15	41 9	95 4
G. C.....	III. 5	Outs. 0-8-0	19	26	4 7	180	23·6	1625	140	1765	3250	..	61 5	39 6	100 11
§N. So. Wales	Fig. 13	Outs. 4-6-0	20	26	5 0	160	27	1786	130	1916	3650	6	56 11	41 10	98 1
Do.	,, 14	Outs. 2-8-0	21	26	4 3	160	29·8	2032	166	2198	3650	6	65 15	41 10	107 5
B. A. Gt. Southern	,, 16	Outs. 2 Comp. 2-8-0	19 27½	26	4 7½	200	24·4	1409	122	1531	3000	4½	58 18	39 5	98 3

* These figures relate to 21 engines of this class built with circular corrugated fireboxes supplied by Deighton's Patent Flue and Tube Co. Ltd., Leeds. It is not in contemplation to build any more at present.

Photographs of this engine, including an ordinary view and a cab view, together with a photograph (for comparison) of the cab view of the "Atlantic" type with "Belpaire" firebox, are exhibited.

§ This is an express passenger engine. Heating Surfaces, see note to Table III.

TABLE VI.—Calculated Tractive Efforts and Boiler Proportions of Locomotives in Table V.

Railway.	Plate and Fig.	Tractive Effort at Rail in lbs. per lb. of M.E.P. in Cylinders.	Total Tractive Effort in cwts. at a M.E.P. = 75 % Working Pressure.	Sq. ft. of Tube Surface per 1sq. ft. of Firebox Surface.	Sq. ft. of Total Heating Surface per 1sq. ft. of Grate Area	Area of One Cylinder in sq. in.	Sq. ft. of Total Heating Surface per 1sq. in. of Cylinder Area.	Sq. ft. of Grate Surface per 1sq. in. of Cylinder Area.
L. & N. W.	III. 2	Equivalent 137·6	184·2	13·2	85·5	(2-15in.dia.) 353·4	4·9	·06
M. R.	III. 3	133·7	156·3	10·4	67·6	254·4	5·6	·08
*L. & Y.	III. 4	192·6	232·1	11 6	78·4	314·1	6·4	·08
G. C.	III. 5	170·6	205·6	11·6	74·7	283·5	6·2	·08
N. S. W.	Fig. 13	173·3	185·6	13·7	71·0	314·1	6·1	·08
Do.	,, 14	224·8	240·8	12 2	73·7	346·3	6·3	·08
B. A. G. S.	,, 16	Equivalent 135·2	181·0	11·5	62·7	(1-19in.dia.) 283·5	5·4	·08

* The boiler proportions are for the "Belpaire" (not circular) firebox.

Of these engines the L. & N. W. is an unusual type for goods trains in this country, in that it has a leading four-wheeled truck, carrying the weight of the four cylinders.

The Midland is a plain, neat engine of the ordinary six-wheels coupled goods type.

The L. & Y. has eight-wheels coupled, with inside cylinders 20in. diameter.

The G. C. has also eight-wheels coupled, but the cylinders are outside and 19in. diameter.

SOME LOCOMOTIVES BUILT IN MANCHESTER FOR RAILWAYS ABROAD.

Fig. 6 on Plate III. is an engine for the ordinary gauge, of which 281 have been built by Beyer, Peacock & Co. for the Dutch State Railways, and in that level country they have given such

satisfaction that they are used, almost exclusively, for both passenger and goods traffic.

The first 176, one of which was a two-cylinder compound, were built with a single axle under the smokebox. In the remainder the axle has been replaced by a four-wheeled bogie, as shown. This is the only engine, among the modern ones dealt with, which has double main frames and outside bogie frames. The cylinders are 18in. diameter × 26in. stroke, and the driving wheels 7ft. diameter.

Some of our members will remember that one of the earlier of these Dutch engines was on view at the Manchester Jubilee Exhibition of 1887, painted a light slate colour, the usual Railway colour being green.

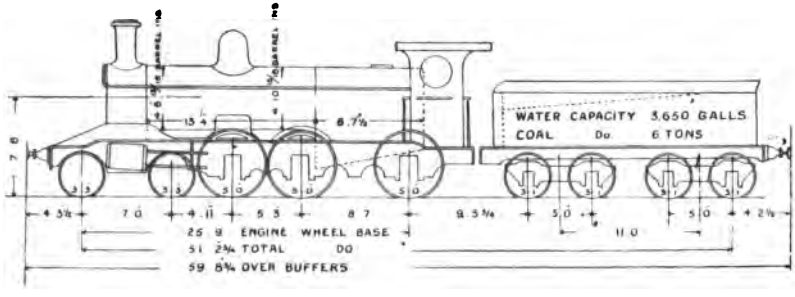

Fig. 13.

Figs. 13 and 14 show two very successful locomotives built by Beyer, Peacock & Co. for the New South Wales Government Railways, of 4-ft. 8½-in. gauge, to the designs of Mr. Thow, Chief Mechanical Engineer. Fig. 13 is a "ten-wheeled" passenger engine with outside cylinders 20in. diameter, six wheels coupled, and a leading four-wheeled bogie.

No sooner had the type of engine been decided upon, than the Railway Commissioners (in 1890) took the bold step of obtaining fifty on the first order, which were delivered the following year, and twenty-five more were placed in traffic in 1901.

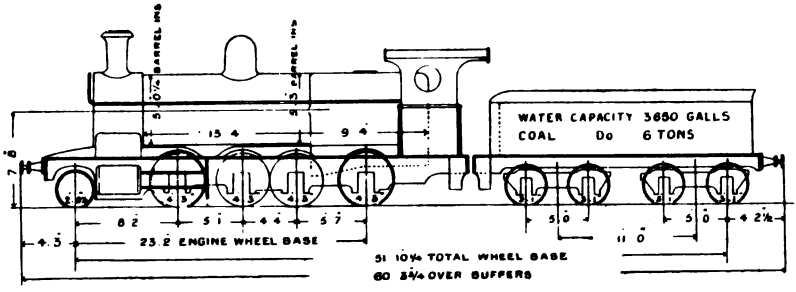
WATER CAPACITY 3650 GALLS
COAL Do 6 TONS
15 4
9 4
8 2
5 1
4 4
5 7
4 5
23 2 ENGINE WHEEL BASE
5 0
5 0
4 2½
11 0
51 10½ TOTAL WHEEL BASE
60 3¼ OVER BUFFERS

Fig. 14.

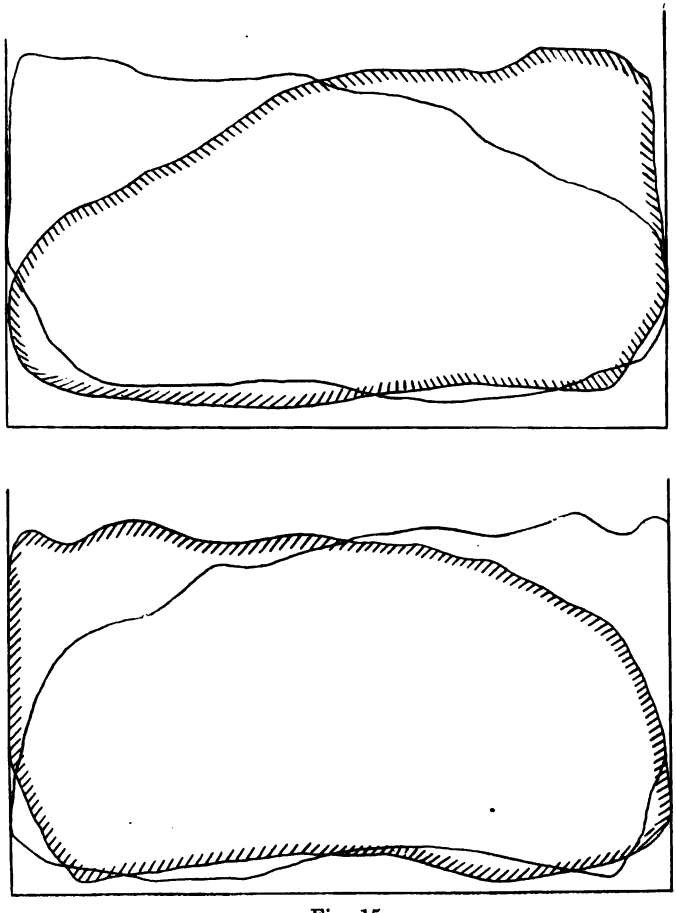

Fig. 15.

Fig. 14 is a goods engine, of a type known as the "Consolidation," with outside cylinders 21in. diameter, eight wheels coupled, and a leading two-wheeled bogie. The first lot were put in service in 1896, and at the end of 1904 there were eighty-nine.

These two classes of engines are required to haul heavy loads over an extensive district, having numerous steep gradients. Fig. 15 are samples of indicator diagrams, to a scale of 80lb. per inch, taken on gradients, the upper one for the passenger engine and the lower for the goods. The following are particulars:—

	Passenger.	Goods.
Grade	$\frac{1}{42}$	$\frac{1}{51}$ to $\frac{1}{42}$
	Tons Cwts.	Tons.
Load behind tender	225 7	354
Miles per hour	20·45	15
Revolutions per minute	114	99
Boiler pressure	165	159
M.E.P.	116·75	125·8
Total indicated H.P.	1,080	1,113

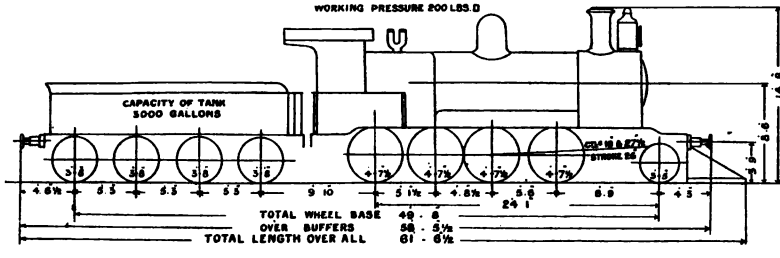

Fig. 16.

Fig. 16 is a two-cylinder compound goods locomotive, eleven of which were built by Beyer, Peacock & Co. in 1902 for the Buenos Ayres Great Southern Railway in South America, of 5ft. 6in. gauge, to the designs of Mr. Gould, Locomotive Superintendent. The country they traverse is vast, and only slightly

undulating, in this respect a great contrast to New South Wales.

Fig. 17 is a combined diagram, constructed from indicator cards taken from the high and low pressure cylinders respectively.

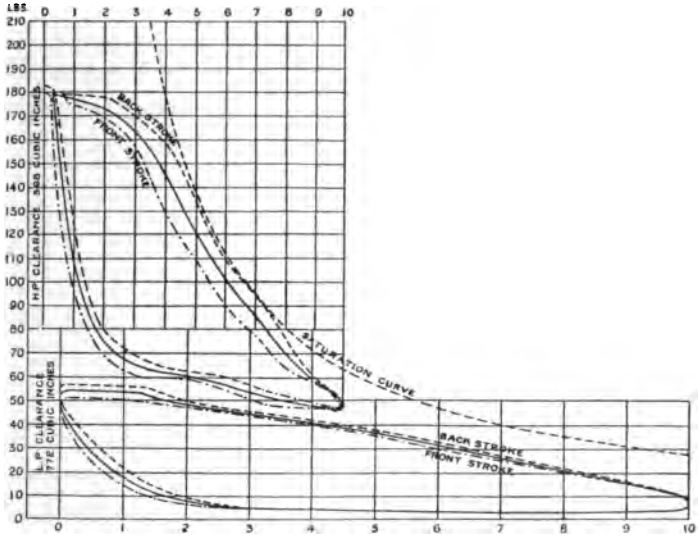

Fig. 17.

The following particulars of the trial have been supplied:—

The load was entirely of wheat in bags. The engine hauled the train up gradients of 1 in 120 and 1 in 200, but in most cases was assisted by the momentum of the train descending a previous gradient.

Total number of axles hauled, 112.
,, ,, vehicles, 29.
,, length of train, 1,091ft.
,, weight ,, 1,164 tons.

On another occasion the performance of one of these engines on a level was:—

Total number of axles hauled, 252.
,, ,, vehicles, 102.
,, length of train, 2,640ft.
,, weight ,, 1,905 tons.

In this case the engine was "stalled" with the middle portion of the train on a rising gradient of one in ninety three, the two end portions being on the level.

Particulars of the last three engines are included in Tables V. and VI.

THE LOCOMOTIVE BOILER.

Referring now to the locomotive boiler (and on this head Mr. Constantine, in his paper on "Steam Generators," anticipated some remarks), larger diameters and higher pressures, without great increase in weight, have been made possible by the use of mild steel plates, and by improved construction in the way of heavier jointing and more elaborate staying. Here again, Mr. Ashbury has reminded us that the late Mr. Daniel Adamson introduced the use of steel for locomotive boilers about 1857. It is not yet exclusively used, a few still preferring to pay for Yorkshire iron, when the pressure desired is not high.

The difficulty of staying the roof of a long round-topped firebox, without the addition of heavy girders, or other objectionable device, is solved in the "Belpaire" firebox, first introduced long ago by M. Belpaire on the Belgian State Railways, where grates of large area were required to consume poor fuel.

The shell of this box has flat sides and top, the sides being stayed together by transverse through stays, and the top stayed to the inner crown by vertical through stays, some arrangement being made over the tube plate to allow of its free expansion. Further advantages are good steam space and the ease with which the crown can be washed through plug holes along each side of the outer shell.

The early Belpaire fireboxes were of iron, the flanged plates being slowly worked on hand blocks. The advent of the hydraulic flanging press, and the more general use of steel plates, much simplified the flanging operation, and now Belpaire boxes are commonly used, as, for instance, on the following engines

illustrated, namely, Midland Passenger, L. & Y. and G. C. Passenger and Goods, Dutch, New South Wales, and Great Southern.

Probably the first engines built in Manchester with this firebox were two by Beyer, Peacock & Co. for the Malines and Terneuzen Railway, in 1872. The firegrate was 8ft. 3½in. long by 3ft. 6in. wide. The whole of the Dutch State engines have had Belpaire fireboxes, the first engine being delivered in 1880.

The vertical stays in a Belpaire firebox are often subject to severe corrosion near the inner crown. Fig. 18 shows the lower portion of a stay taken from one of the G. C. engines, the dotted line representing the original shape. To combat this action the Railway Co. are dropping short tubes over the stays, as they are inserted in the box, and filling up the small annular space between each stay and tube with Portland cement. The same method has been used by others, and it is said with success.

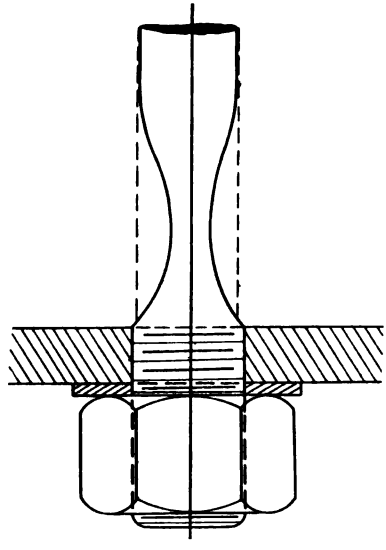

Fig. 18.

After long trials of several materials, many Railway Co.'s now use boiler tubes made of copper, as were those in the "Rocket." The Midland chiefly use copper, and the L. & N. W. use either copper or steel, depending on the nature of the water in the district in which an engine will work.

On the Midland Railway no boiler blow-off cocks are used. To empty the boiler a wash-out plug must be drawn, which cannot safely be done while the water is hot, and so the inner plates are saved from damage through being sprayed with cold water when at a high temperature.

Water-tube boilers, both partial and complete, have been on their trial on some railways in recent years, but are not yet in anything like general evidence.

COMPOUND LOCOMOTIVES.

Much information has been gathered, with reference to several locomotive details, from the four Manchester railways under consideration, but space forbids further description.

A few words ought, however, to be said about compound locomotives. Of the engines illustrated, the Midland Passenger is a Smith's three-cylinder compound, the high-pressure inside, and two low-pressure outside, all connected to the front coupled axle. The L. & N. W. Goods is a Webb's four-cylinder compound, having two outside H.P. cylinders, and two inside L.P. cylinders, all driving the leading coupled axle. The B. A. Great Southern Goods is a two-cylinder compound, both outside.

The ratios of cylinder areas for the above are

	M. R.	L. & N. W.	B. A. G. S.
H.P. to L.P. as 1 to	2·44	1·86	2·09

The Mallet compound, Fig. 12, has the H.P. on the main frame, between the two groups of wheels, and the L.P. on the six-wheeled bogie under the front end of boiler. The ratio is 1 to 2·56.

Many compound locomotives have been built in Manchester. Sharp's, before removing to Glasgow, built three compounds, of Webb's three-cylinder system, and Beyer, Peacock and Co. have built about 360 compounds, including some conversions of engines already delivered. With the exception of one Webb's three-cylinder, all these 360 were Worsdell and Von Borries' two-cylinder compounds. As already stated, one of the Dutch engines was a compound, and so were two of the New South Wales Passengers. In this latter case the cylinders were outside, and the L.P. was so big that it had to be made into a twin cylinder (with a common valve chest, to clear station platforms). These two locomotives were subsequently converted into simples.

The writer has found that, in some cases of compound locomotives, which were working beside corresponding simple engines, and, as far as could be ascertained, were of equal power, the ratio of (the area of H.P. cylinder × working pressure in compound) to (the area of simple cylinder × working pressure in simple) was approximately as 100 to 80. Hence the rule for equivalent tractive effort made use of in the Tables IV. and VI.

Much might be said for and against compound locomotives, but there is no consensus of opinion, and probably never will be. The continually varying duty of a locomotive is so very different from that of either a marine or stationary engine that comparison with them fails.

CONCLUSION.

In conclusion, what is to be the future of railway motive power? Steam locomotives are growing apace, and there appear to be limits beyond which they cannot, under present conditions, go.

The next fifty years will witness more marked changes than those we have considered to-night. Is the steam locomotive soon to be replaced on long distance journeys by electric traction,

either of the single or multiple unit system? It may, if electric traction can be made remunerative. Probably we shall hear something about this when the succeeding paper, on "Modern Electrical Developments," is read by Mr. Metzger.

Or is the steam turbine, or internal combustion engine, to give some unexpected turn to railway working? Who knows?

> "If you can look into the seeds of time,
> And say which grain will grow and which will not,
> Speak."

Acknowledgements.—Thanks are due to numerous gentlemen who have so readily supplied photographs, drawings, and other information for this paper, the following being among the number:—

Mr. S. W. Johnson, Nottingham.
,, Thomas Ashbury, Manchester.
,, G. Whale, Chief Mechanical Engineer, L. & N. W. Railway, Crewe.
,, R. M. Deeley, Locomotive Superintendent, Midland Railway, Derby,
,, G. Hughes, Chief Mechanical Engineer, L. & Y. Railway, Horwich.
,, W. Thorneley, G. C. Railway, Gorton.
,, J. H. Sharp, North British Locomotive Company, Glasgow.
,, J. Bolas, Nasmyth, Wilson & Co., Patricroft.
,, J. Scoular, N. S. W. Government Railways, Sydney.
,, R. Shepherd, B. A. Great Southern Railway, Buenos Ayres.

Illustrations "Hibernia" and "Vulcan" are copied by permission of the Institution of Mechanical Engineers (see Proceedings, 1890, Plates 47 and 59).

APPENDIX.

The following notes relate to the performances of some of the modern locomotives discussed in the paper:—

MIDLAND RAILWAY.

Compound Passenger. A description of this engine will be found in *Engineering* for August 15th, 1902, the number for

February 6th, 1903, containing a full account of its performance, with indicator diagrams, etc., and that for March 27th, 1903, acceleration and velocity curves.

Express Goods. "These engines are scheduled to travel on the line between London and Leeds with a load of 496 tons at 40 miles per hour, or with a load of 626 tons at 30 miles per hour."

LANCASHIRE & YORKSHIRE RAILWAY.

Express Passenger. Average load hauled behind tender, 237 tons at an average speed of 52 miles per hour, the gradient for 1½ miles being 1 in 97.

Express Goods. The corresponding figures are 800 tons at 20 miles per hour. with 5 miles of 1 in 150.

NEW SOUTH WALES GOVERNMENT RAILWAYS.

Express Passenger. The longest run with this engine in passenger service is 162 miles over a mountain section, with loads behind the tender varying from 155 to 230 tons on down journey, and from 190 to 240 tons on up journey.

Heavy Goods. The longest run with this engine is 140 miles over a mountain section, with loads behind the tender varying on both up and down journeys from 297 to 540 tons.

According to Mr. Bolas's paper of 1888, the "Waverley" took a train of 80 tons from Euston to Crewe, 158 miles, without a stop, at an average speed of 53·5 miles per hour.

DISCUSSION.

Mr. Thomas Ashbury said, that as already mentioned, this paper was an historical paper, therefore those who spoke might be pardoned if they followed a little on the historical line. He remembered as a boy of six or seven years old, looking with delight upon the locomotives which were being built by Messrs. Nasmyth, Gaskell & Co., at the Patricroft Foundry. In 1846, his home, and his family's works were directly opposite those of Messrs. Sharp, Stewart & Co., in Great Bridgewater Street, Manchester, and it was his boyish delight to see every Monday morning, a new locomotive engine turned out from Sharp's, hauled by perhaps ten or twelve big horses.

In 1856, fifty years ago, he was working in the Loco. Dept. of the L. & Y. Railway Co. under Mr. Jenkins, and well remembered having to do with some of the very early locomotives put upon the L. & Y. line, especially with some engines which had not been referred to in the paper, which were built by Messrs. Bury, Curtis & Kennedy, of Liverpool; these engines they designated "coffee-pot" engines, owing to the shape of the firebox end of the boiler being somewhat similar to a coffee-pot.

Reference had been made to engines which had been made principally in Manchester and the immediate neighbourhood. Now, though Manchester was early engaged in the making of locomotives, he ventured to assert that in all the works which made locomotives in Manchester, the work had been done in the best possible manner.

It had been his privilege, when away from home, to see some of the engines made in the Manchester district; and he remembered on one occasion when in Stockholm, going through the Atlas Engineering Works there. After being entertained by the Managing Director of the Company, he was asked how he liked

the Works, to which he (Mr. Ashbury) replied that he could almost have imagined himself being back at home, and walking round Messrs. Beyer, Peacock's Works, as the Atlas Works were laid out on the same lines. The Managing Director then explained that he was for three years a premium apprentice of Mr. C. F. Beyer, and did not know of any better example than to make his works on the same lines; so he had copied and taken note of everything at Beyer, Peacocks, and had laid out the Atlas Works on that plan. On the same journey he met the Locomotive Superintendent of the Royal Swedish Railway at Malmö; and in looking at some Beyer, Peacock engines which were then under repair, and some Borsig engines from Berlin, also under repair, the Loco. Superintendent told him that the best engines on the Royal Swedish Railways were those from Gorton. He said that these engines after having been in the shop and had an overhaul, went out for service, and they heard nothing more about them for months; but in the case of the Borsig engines they had to keep spare engines at different centres, as they did not know when the Borsig engines would fail, not seriously, but sufficient for a time, more or less, to throw them out of traffic. This Loco Superintendent gave an unqualified approval of the economical and successful working of the Beyer, Peacock engines. On another occasion, on behalf of his firm, he had to take over ten Beyer, Peacock engines that had been built for a railway in Spain; it was during the Carlist War, and six of these engines were away in the mountains and could not be seen, the railway track and bridges being broken; but he (Mr. Ashbury) then had an object lesson in the character of good work which he had never forgotten. He wanted to sell these engines to some gentlemen in Barcelona, who had not seen them, and he (Mr. Ashbury) could only depend on the drawing and specification of the engines, but the reputation of the name of the firm on those engines, Beyer, Peacock & Co., enabled him

to sell the engines without being seen by the purchasers—they could not be seen for some months after—at £100 more per engine than the purchasers could have bought at that particular time new engines. That was entirely owing to the character of the work, that character which two such distinguished men as Beyer and Peacock started well and maintained.

Some thirty or more years ago he remembered going through the pattern shops with Mr. Peacock, who pointed out some patterns, and said they were the patterns of the very first five engines they had made, that these patterns had never been altered, and if they were asked to supply a new cylinder or other part they could replace it at once without any question of the manner of the work. That was something in favour of good work.

He also remembered another occasion when travelling down the Eastern coast of Spain, he went to look at some American engines which had just been delivered, and were alongside some engines delivered from Manchester, from Sharp, Stewarts, and Nasmyth, Wilsons', and as he looked at them he was astonished to see the poor character and finish of the work on the American engines. The dome for instance, instead of being what would have been turned out by Manchester firms, a nice dome, perhaps in metal, polished smooth, was in cast iron painted over with common black varnish and the fins of the casting from the foundry had not been chipped off.

Mention had been made in the Paper to the slip on curves. He remembered many years ago an engineer, whom he believed was on the St. Helens and Widnes Railway, brought out a device to overcome this, in which he introduced a spring between the underside of the tyre and the outside rim of the wheel, with two rings to keep the tyre in position. That allowed the tyre to slip on a curve, but as brakes had to be applied it was found to be a very serious inconvenience. A lot of these wheels were made for abroad. The theory seemed beautiful and captivating,

but when they got abroad the complaint came back that every tyre was loose. The tyres of course were made loose, that was the patent; but they would not have them loose and they had to go back to the old-fashioned way.

Some types of Locomotives had not been mentioned in the paper, but if space had allowed the author would no doubt have made some reference to them. For instance, the Fairlie double engine used for mountain climbing, and made by the Yorkshire Engine Co. Sheffield, could have been compared with other engines made for mountain climbing, such as the Modern tank engine for the Natal Government, with 16 wheels, 10 of which were coupled, and weighing 70 tons in working order on the narrow gauge of 3ft. 6in., compared at the other extreme with a dwarf passenger locomotive, 4 wheel coupled, 9in. diameter, working on a 10½in. gauge, drawing 6 passenger cars carrying 24 passengers.

One of the most remarkable locomotives he had seen, and which had naturally not been referred to in the paper, was a new and different type (a French design) of a locomotive to run on a mono-rail. Many years ago a contract was entered into in which he was an interested party, for the construction of a railway in Portugal on a mono-rail system. The contract was placed in Manchester for the rolling stock, and Sharp, Stewarts' made the locomotives. The locomotives were to run on a single line with single wheels one after the other; and with a kind of feelers, like oars in a boat, protruding on each side, and on the end friction rollers ran on hard wood let into the ground. He went out to Portugal and saw what was left of this railway, for unfortunately as soon as it got ready to work there was no money forthcoming, and contractors and tradespeople on the spot began to take their own goods back, until it became a regular scramble as to which could get their stuff back again, and they cleared all off until only the permanent way was left.

Another remarkable locomotive he had seen was in Coney Island, U.S.A., where there was a mono-rail system, the locomotive having one driving wheel 7ft. 9in. diameter on the tread, 8ft. 0in. diameter over the flanges, and this wheel placed directly under the centre of the locomotive boiler with two small trailing wheels behind, all working on one line; the idea was that a single line of railway should be a double line at once without altering the railway lines. The carriages were two storeys, 14ft. high and 4ft. wide—looking very much like a St. Helens glass packing case on edge, running on wheels—and carried 108 passengers, attaining a speed of equal to 90 miles an hour on a line from Seabeach to Brighton in Coney Island. The line was only 1¾miles long, and they had 100 trains a day running with 100 passengers each on the average. This line was the forerunner, or intended to be the forerunner, of other lines which were going to spread all over America and double at once all the railway output. He (Mr. Ashbury) did not think, however, that that had been accomplished, but he had noticed some few days ago that the Westinghouse Company had received an order from James N. Vanderbilt, the inventor, to build a car to cover the distance between New York and Chicago, nearly 1000 miles, in eight hours, being a kind of mono-rail engine running on a centre rail put between the ordinary rails, with four wheels, placed one ahead of the other, and kept upright by rollers running on what are now the present rails.

He wished to express his personal obligations and thanks to the author of the paper for the very interesting matter given, and for the resume of work so much of which was local and in which the members took so much interest.

Mr. R. R. Lister said that he had had great pleasure in listening to the paper, as an old Beyer, Peacock man, and he was much gratified by the remarks and high praise given by

Mr. Ashbury respecting the high quality of work turned out in this district, and especially by the firm of Messrs. Beyer, Peacock & Co.

Some reference had been made in the paper to compound locomotives, and he thought that perhaps a few words on that subject would be acceptable. As was well known, the great success of compound engines had been largely in cotton mill driving and marine engineering; and that had been due, he thought, almost entirely to the fact that the loads were uniform; this was seldom the case with locomotive work, and the most successful field for compound locomotives so far had been in South America, chiefly in the Argentine Republic. This was due to that being a vast country and practically level, where they had long distances to haul and got fairly uniform loads. There the compound engine had been a practical success to such an extent that they kept on ordering them year after year. The question of fuel was an important one, as practically all the coal had to be imported, and the saving in coal, and also of water, which was very difficult to get of suitable quality, was well worth some consideration.

Reference had also been made to two locomotives for New South Wales of similar type to the standard passenger engine. These engines, after being at work for some little time, were converted into simple engines. He thought the reason would be very easily found, and was due to the fact that for some little distance from Sydney inwards the line ran over practically level country, but afterwards the engines had to climb the Blue Mountains. This Blue Mountain section was exceedingly difficult to work, there being steep gradients, some of 1 in 33, and some not quite so bad; but he thought the failure of these two engines had been due to the work to be done on that particular railway being of such a varying character. These engines were found not to run freely downhill, owing to the

pumping action of the large low pressure piston when running without steam.

Mr. J. Parry thought they would all agree that they had had a very good paper; those who knew Mr. Rendell expected nothing else.

The author had mentioned that a cause of retardation was that in rounding a curve the wheels were like gyroscopes, each endeavouring to keep its own plane of rotation, thus causing flange friction. He thought that the author had fallen into a trap. In one form of gyroscope there was a rapidly revolving wheel at one end of a straight arm or spindle (the centre line of the arm or spindle being the axis about which the wheel revolved), the other end of the arm being supported by a ball and socket joint on a vertical pillar. If left alone the arm would keep a fairly horizontal position, although only supported at one end; *but it would acquire a motion round the vertical pillar.* This latter motion was a very important factor, because, if the arm was restrained from such movement it would fall in the same manner, and just as easily as if the wheel was not revolving. Something similar to this occurred in the case of a wheel going round a curve, the difference being that moments acting on a vertical plane were replaced by moments acting in a horizontal plane, and *vice versa.* So that if the plane of a wheel was restrained from moving round a horizontal axis, as was the case with railway wheels, it could be made to turn round a vertical axis just as easily when revolving as when not revolving. Therefore, gyroscopic action did not retard the wheel or cause flange friction.

The rule given by the author for weight of rails appeared to be applicable within small limits only.

Respecting the special feature of the Atlantic type of engine that the coupled wheels were all in front of the firebox,

he thought this a very great advantage over an engine with the coupled wheels, one pair in front and one pair behind the firebox; because with the latter the distance between the axle centres was *variably* affected by the expansion of the frames due to heat from the firebox, as no corresponding variations of expansion took place in the coupling rods, something like a tug of war was set up at times.

In a paper before the Association, by Mr. E. G. Constantine, on "Steam Generators," water-tube boilers were referred to, and had been proposed for locomotives. It was a well known fact that a locomotive boiler would make more steam when used as a locomotive boiler than as a stationary boiler; the reason of this was that the motion of the locomotive caused the water to wash the heating surface and free it of steam bubbles. In a locomotive boiler of ordinary type the water was free to move in any direction, but if a water-tube boiler was used the water would only be free to move in the direction of the tube's length. Water-tubes had been put into the firebox. Now it should not be forgotten that the firebox of a locomotive boiler was also the combustion chamber, and as much room as possible was wanted there, and further, what was heating surface for the water, was cooling surface for the gases, and the gases were cooled before being perfectly burnt. He had not heard of any success being obtained with such arrangement, nor of anybody recently putting them in.

Respecting the Belpaire firebox solving the difficulty of staying the roof of a long firebox without the use of heavy girders, he might say that with roof-bars there was a terrible strain on the tube plate, and also on the back plate, and if sling stays were attached to the top of a round topped box, as was often done, the additional support was practically worthless. He had seen the top of a box come down when tested $\frac{7}{32}$nds of an inch, and it took a permanent set.

A further objection to roof-bar stayed fireboxes was that they soon got choked up. He had seen one so much choked that the roof-bars could not even be counted when the box was taken out.

The reason that the Belpaire firebox had not come into use in this country earlier was owing to the difficulty and expense of flanging the throat plate. This had been overcome; it was now easy to flange the plate at one heat

In regard to the ferrules put on the vertical stays, it was only about three years that these had been in use, and he did not think anybody could tell how they were going on practically; he, himself, thought that their value depended too much on the integrity of the workmen who filled them up with cement.

The author had mentioned the use of tubes, copper or steel. The Great Central Railway Company were now using steel and charcoal iron exclusively. It was at first thought that copper ends were necessary to expand into the copper tube plate, because of the difficulty of expanding a hard metal into a soft one. These copper ends gave trouble owing to the expansion by heat, the steel part of the tube would not give, and all the work was thrown on to the softer copper, which gave way.

He was rather surprised to note that Messrs. Galloway had built so many locomotives as stated in the paper, as he had always been under the impression that they only built one. He supposed, however, that the author had made more enquiries into it than he had. The late Mr. John Galloway, Senr., had said that the building of a locomotive was absolutely nothing compared with the getting it out of the works, and to the railway afterwards.

He would also like the author to say what he meant by locomotives in service. How was it the number of engines on the Great Central Railway was only 623 at the end of June, 1905, when the total at the end of 1904—six months earlier—was 1,063?

Mr. W. Ingham said the author had given them a paper on a very attractive subject, and one in which almost all the members could take an interest. He had hoped that some of the members who had had special experience in locomotive engine work would have joined in the discussion on this paper. He, himself, proposed only to devote a few words to what the author described as the "lungs" of the locomotive—the boiler—as that was the part with which he had had more to do than any other.

One feature which had not been mentioned in the paper, and it seemed to him a very important one, bearing on the longevity of locomotive boilers, was the manner in which the barrels of locomotive boilers were constructed some 20 or 30 years ago, and the way in which they were now constructed. It was the custom, 30 years ago at any rate, to have lap joints both at the longitudinal seams and ring seams; and it was part of his (Mr. Ingham's) duty at one time, before the Boiler Explosion Acts came into force, to investigate most of the explosions which took place in various parts of the country. He remembered at least 20 locomotive boilers which exploded from one particular defect, (the greater number of them by one particular maker in Scotland), and that was grooving at the longitudinal seams. The comparatively thick plates and high pressures, for which locomotive boilers were constructed, with small barrels, had the effect of setting up a mechanical action at the longitudinal seams, and the "grooving" which resulted was often so fine at the edge of the overlap that it could not possibly be seen in many cases upon ordinary inspection. Now, with butt joints, and butt straps, the barrel was made truly circular, and that action did not take place; so that one very important feature to be noted between locomotive boilers of 50 years ago and now, was the reduced number of barrel explosions. He could give particulars of a large number which had exploded from that

cause in the period above named, but he had not noticed any of late years.

The effect of the mechanical action, which was caused by the tendency of the pressure to cause the barrel to assume a truly circular shape, and the small movements due to alternations of pressure, was, of course, greatly aggravated where the water was at all corrosive, and sometimes resulted in the formation of longitudinal grooves, from $\frac{1}{4}$in. to $\frac{3}{4}$in. wide. In many cases, however, the action was confined so closely to the edge of the overlap that it could not be detected before explosion occurred, and it seemed almost as though the plate had been cut with the point of a sharp knife drawn along the edge of the overlap. The grooving occurred mostly in the lower part of the locomotive barrel; and in the case of the explosion of one locomotive boiler at a colliery in Scotland which he investigated, the locomotive was lifted violently upwards, turning a complete somersault and coming down on the funnel, and rebounded so that it finally alighted on the other line of rails on its wheels as though nothing had happened, beyond the funnel looking the worse.

The author remarked that the heavier loads and higher pressures now adopted were not in favour of longevity, but it seemed probable that the many improvements in points of detail, and the generally superior manner in which locomotives were now made, would probably more than counterbalance any drawbacks resulting from these factors making for a shorter life.

Mr. A. Gem congratulated Mr. Rendell on his paper; he had dealt with the subject in a very admirable manner. The historical nature of the paper, however, did not lend itself much to discussion, but he had noted that the author had referred to the number of engines on the Great Central Railway. When he (Mr. Gem) entered their shops in 1888, the number of their

oldest engine was 561, and when he left in 1896 the number was 775. He thought, therefore, that there was some mistake about Mr. Rendell's figures.

In connection with the question of increased hauling capacities, it seemed to him that four-cylinder engines, two outside and two inside the frames, driving on to separate axles, with cranks at 90 degrees, would be the type to ultimately come into use; this would give more uniform turning moments, and an engine more easily balanced, and could be built of much greater power than any engine now running.

He considered Mr. Robinson's Great Central engine (Fig. 1, Plate III.) a very serviceable design, the cylinder being outside there was no crank axle. Anyone acquainted with locomotive work on a railway would be aware of the enormous number of failures in crank axles, and could appreciate the importance of abolishing the crank.

Respecting the author's remarks on the Belpaire firebox, he was quite in agreement with these, as with this type you could calculate exactly what stress you had on your stays; but with the round topped form of boiler, and girder stays, you never knew what portion of the work the sling stays were doing.

The author had not touched on the question of superheating at all. This seemed to have been adopted a good deal on the Continent recently, and perhaps Mr. Rendell in his reply would have something to say upon the subject, and as to the advantages of superheating.

Mr. Z. Tetlow said he was very pleased to have a few remarks to make, and would like to congratulate Mr. Rendell on his paper. He was sorry that the print of the corrugated firebox had not been illustrated, as it was a very interesting experiment. The L. & Y. Railway Co. had 21 engines of this class.

Originally the firebox tube plates were steel, $\frac{5}{8}$in. thick, but the tubes could not be kept tight; the tubes originally were solid drawn weldless steel. The thickness of this tube plate was, to all intents and purposes, American practice. Then an experiment was tried of brazed copper end (steel tube with copper end brazed on), the copper end at the firebox tube plate, but no satisfaction was given with this arrangement. The old type of copper box was then tried, 1in. thick, with steel tubes, and they had never had the slightest trouble since from leakage in the tubes. The corrugated flue costs about £60. It was made by Messrs. Deighton, of Leeds, and was the old type of flue with even corrugations patented by Samson Fox. A comparison as to cost with Belpaire copper firebox as it is, would be about £360 to £400, to £60 for the corrugated.

These engines, 21 in number, had had practically no repairs done to them. The flues were 5ft. diameter and 10ft. long, being one of the largest flues made in the country. One firm who specialized this make could not contract to do the flues, and Messrs. Deighton took the matter in hand. He understood, however, that an injunction had been given, and they could not make any more of that class, except through Messrs. Brown, or The Leeds Forge Co.

There was one trouble with this boiler that had not been got over, and that was the circulation of water; and it was only a question he (Mr. Tetlow) thought of a matter of experiment, which the Americans had tried—that of injecting a jet of steam from an engine coming into the shed to be cleaned. This would not lead to waste, and would promote circulation. It was found that after steam pressure had been got up in this class of engine there was no trouble in maintaining it, and it showed that something had to be done in the circulation of the water, because, if the engine was run backwards and forwards the pressure soon rose, and there was no further trouble.

In this class of boiler the cost was worth while considering, as the cost of a Belpaire box was nearly six times as much, and there had been practically very little repairs done.

One speaker had mentioned about the capacity of trains and what they could do in England. Unfortunately on the L. & Y. Railway they had very small sidings, and it was a common occurrence for these very long trains to block other trains on the main line, and they had to shunt from the cross over road on to the other line to do this to keep the traffic working. There was one thing that had done a lot to obviate this, and that was the water pick-up arrangement of Mr. J. Ramsbottom's invention. This arrangement of the water scoop used to be pulled out by hand and foot lever, and on many of the railways it was worked by being connected to either the Vacuum or the Westinghouse brake, and by turning the handle of the actuating cock to either "in" or "out" positions. As the detainments were so great at the different stations, until they got more siding accommodation on British railways, he did not think they would be such a great success as in America, where they could run right away for hundreds of miles, and there was no shunting.

In connection with Mr. Gem's remarks with reference to crank axles, the L. & Y. Railway Co. had a large number of crank axles which were made out of one ingot, but now they were building them up, and pressing on both the sweeps and every other part, and since they had got the right contraction they were giving much better results. They (the L. & Y.) had also done a little bit in superheating on the 1400 Class 6 engines of this type, as illustrated by Fig. 6, Plate II., and 90 degrees of superheat had been obtained in a very short run. The arrangement was for the steam to enter the superheater, which had a series of diaphragms placed in it, with the tubes passing through, and the steam had to pass up and down between these diaphragms before it got to the cylinders; and the experiment

had been a success as far as the L. & Y. Railway Co. had tried it. They were now trying one of these engines fitted with "Serve" tubes.

The L. & Y. Railway Co. were also trying a system of Druitt-Halpin's Thermal Storage Heater, see Fig. 3, Plate I. This was a receptacle for water placed on top of the ordinary boiler, and was supposed to give a great saving in fuel. Its adoption in central power stations, had, he understood, been attended with good results. He had no figures to then give in support of his contention.

With regard to the life of boiler and firebox, there were great differences. Nowadays, copper was being made so pure on account of the requirements of Electrical Engineers, that the life of the copper firebox was not so long on account of the copper being short of arsenic.

With regard to the question of copper and steel tubes. Where the water supply was bad, copper tubes were undoubtedly the right thing; and even when the tubes had to be taken out the old material fetched a good price for scrap. In some cases the price obtained for scrap copper tubes was as much as was paid originally; this was owing to the present boom in copper. Where the water supply was good solid drawn weldless steel tubes were doing excellently, and if these tubes could be got with a skin of black oxide, as was seen occasionally, they would last very much longer. The L. & Y. Railway Co. had tried steel tubes with a copper sleeve on, these were a failure, as on being expanded the copper left the steel.

Another thing which the author had not mentioned was in relation to the improvements in valve gears, and the various ones which were being tried, for instance, the "Marshall" valve gear which he (Mr. Tetlow) saw on two locomotives a few weeks

ago on the East and West Yorkshire line. One loco. was fitted with this "Marshall" gear and another with the ordinary valve gear. The latter had had all repairs done to it, *i.e.* pistons, new slide valves, and driving wheels turned up, and all journals carefully bedded. This engine hauled a train up a bank of 1 in 30, curves of three chains radius, with the boiler blowing off at 160lbs. pressure. The greatest load which the engine could pull up a steep bank was ten 10-ton wagons, another half truck would have been too much. The sister engine, fitted with "Marshall gear," had no difficulty in hauling sixteen 10-ton wagons, in the third notch. The other engine had run in "full gear." They also increased the orifice of the blast pipe ¾in., and he (Mr. Tetlow) examined both smoke-boxes. In one it was quite full of ashes, from ⅛in. to ¼in. in size, and in the other (Marshall gear) there were very few, and these were very fine. The gear costs very little more than the ordinary link motion, and he understood the G. S. & W. Railway of Ireland had tried an Engine fitted with this gear, and had got 10 miles per hour more out of it than with a sister engine fitted with the ordinary gear. He (Mr. Tetlow) thought it was well worth a trial on the English Railways. It had not been tried as it should have been, and it had been very successful both in colliery winding and other engines.

Another arrangement of valve gear which was being largely tried in the United States was the "Alfree-Hubbell," which, it was stated, was giving an economy of 14%.

Mr. J. Hardisty said that for many years fireboxes had been made of copper, and also the tubes, but of recent years it had become the fashion to use solid drawn steel tubes in place of copper and brass; the German railways used nothing at all but steel tubes, and most of the British railways were using them almost exclusively.

The trouble that arose when steel tubes were first introduced was leakage at the firebox, because of the different expansions of steel and copper. Several of the engineers had spoken to him about that matter, and he had said, "you should use materials having the same co-efficient of expansion." For many years the Indian States Railways had been using steel fireboxes. He did not know what their tubes were, but thought they were mostly of brass. There they had apparently reversed the English practice by using a material for their fireboxes having a lesser amount of expansion than the tubes, with the result that they never had any trouble with leakage. The whole matter was one of expansion.

Mr. Edward M. Gass in a written communication, said he wished to add his congratulations to Mr. Rendell for the large amount of interesting information contained in the paper, and also, in response to the President's remark, to add a short communication.

On Page 26 the author had stated that difficulties were fast appearing which prevented a fair sized engine being put on the ordinary 4ft. 8½in. track, as larger cylinders could not be placed either inside or outside the frames. This remark might apply to the two-cylinder engine, but it appeared to him (Mr. Gass) that locomotive engineers would eventually have to turn their attention either to the four-cylinder "simple" or "compound" type. 21in. diameter was about the largest pair of cylinders which could be placed either inside or out. Applying these to a 6ft. driving wheel, and assuming a boiler pressure of 180lbs., a piston stroke of 26in., and a M.E.P. of 75% of the working pressure, a tractive effort of 21,500lbs. would be obtained. Supposing, in place of the two cylinders, four of 17in. diameter were employed, the tractive effort would be raised to 28,180lbs., an increase of over 30%.

The question therefore arises, would it be possible to get in a boiler within the British railway loading gauge of sufficient power to meet the demand of the four cylinders. If the Atlantic type of engine was adopted, there would be no obstacle in the way, as a broad firebox extending over the frames could be employed, or another way would be to terminate the main frames in front of the firebox in a strong steel casting, to which would be secured the wider spaced frames extending along the firebox sides. With a broad firebox of this description, 50 square feet of grate surface, could be obtained with the box not excessively long. Assuming 70 square feet of heating surface to one square foot of grate, there would be then a boiler of 3,500 square feet of heating surface, and which would be ample to supply the cylinders. This size of boiler could easily be arranged within the loading gauge if a 6ft. wheel was used. Many of the express trains of to-day were run with even smaller wheels. A difficulty, however, would now appear in regard to the necessary adhesion. The maximum load allowed per axle was 20 tons, or for the two pairs of driving wheels, 40 tons. Assuming 600lbs. per ton, which was the maximum, there would only be obtained an adhesion of 24,000 lbs., which was not sufficient to absorb the tractive effort.

It seemed to him, therefore, that the permanent way was the obstacle to the employment of a more powerful engine for passenger work. If the road bed and bridges were made sufficiently strong to allow a greater load per axle, it was possible to make an engine quite 30% more powerful than the largest yet running on British lines.

On the motion of the President (Mr. R. Matthews) a cordial vote of thanks was passed to the author for his paper, which he briefly acknowledged, promising to reply in writing later.

Memorandum.

It is with the deepest regret that we have to record that immediately after the above meeting the author took seriously ill, and never sufficiently recovered to enable him to complete the paper. He passed away March, 1906.

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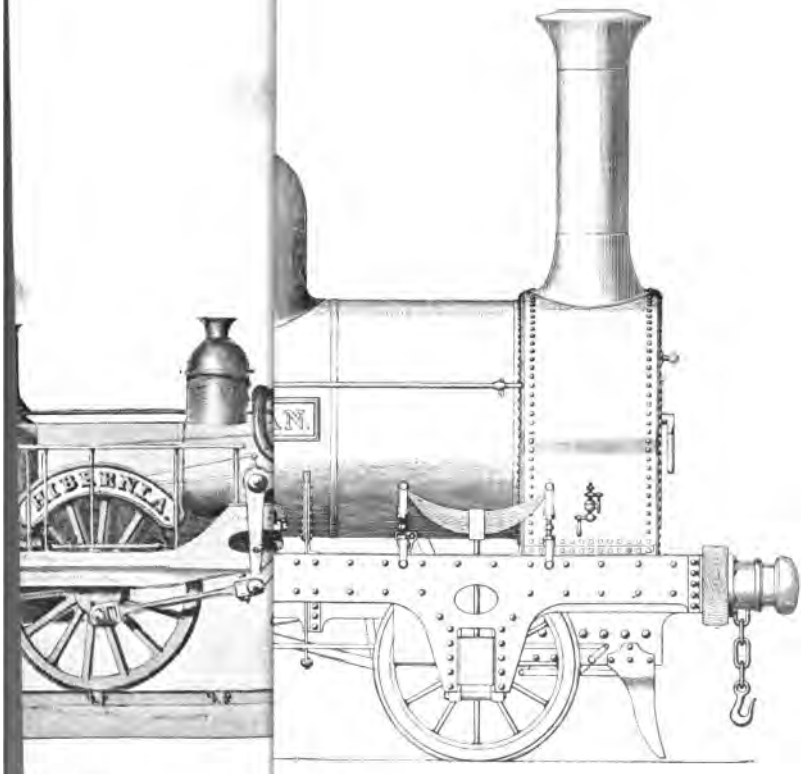
3 Plates follow illustrating this Pater.

THE ST

Co., 1

Plate 1.

THE STEAM



Co., 1834. 1849.

LOCOM

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UNIV. OF MICH.

MODERN ELECTRICAL DEVELOPMENTS.

READ SATURDAY, 27TH JANUARY, 1906,

BY

MR. G. F. METZGER, M.Inst.C.E., M.Inst.E.E.,

MANCHESTER.

It is difficult to understand why fresh subjects on electrical engineering require so much consideration on the part of the authors, this branch of engineering having, during the last few years, made such enormous progress, resulting in a mass of information having been reaped in consequence by those responsible for new discoveries and innovations of all descriptions.

The author having been asked by your esteemed president to contribute a paper on modern electrical development, and the title therefore having been fortunately chosen for and not by him, he has endeavoured to bring before you some of the more important items in this vast subject, and with which he cannot pretend to deal in detail.

This being a society whose dealings are more closely allied to mechanical engineering, he has purposely refrained from going too deeply into the technics of electricity. Neither does he invite discussion on the developments in the use of electricity as applied to medical science, such as X rays or chemistry, in connection with electro-metallurgy and bleaching, telephony or wireless telegraphy, but rather confines himself to electric supply as given from central stations or private plants for lighting, tramway, or motive power.

CENTRAL STATIONS.

Although many papers on the design of central stations, as well as their general running, including statistics on works' costs, have been given by those in command of particular schemes, it can hardly be said that any radically fresh principles have been disclosed which would materially affect the results. Every scheme must necessarily be considered on its own merits, it having to suit special circumstances in each case, such as local quality of coal and methods of handling same at the disposal of the undertakers, absence and nature of water for condensing and feed water purposes, but especially the nature of the load, whether chiefly house, shop or street lighting, traction or power load, or the supply in bulk.

The publication of statistics, therefore, on the cost of generation and the comparison in this respect between one works and another, although useful, cannot be of great value, as no two stations are rnning on exactly equal basis. In addition to the local conditions above mentioned, other factors are often suppressed, which, when known, give a different complexion to the figures quoted. Thus comparisons between central stations, some of which obtain their coal at 5s. per ton and others at 25s., some have an ample supply of water from which others are debarred (this in many cases due to want of forethought when the works were originally designed), some are compelled to be satisfied with a low load factor, owing chiefly to shop or residential lighting, whilst others are more favourably situated by having a good combined tramway or power or street lighting load for filling up the gaps in the peak, are misleading.

They become still more so when the low works costs, boasted of by some central station engineers, are partly obtained by the salaries of those responsible for extensions or new work of any description being placed to capital account (although this procedure is not permitted by the Board of Trade in municipal

undertakings), or that premium pupils with either small or no wage at all are entrusted with posts in the works which should be occupied by qualified and, therefore, properly paid officials. This and similar methods must necessarily be adopted in the smaller stations if works costs are to be kept low to prevent a call on the rates.

When this is the case, the ownership of such stations ought never to have been entrusted to municipalities, but they are now-a-days so eager to prevent private capitalists entering what they consider their sphere of operations, that they apply for a provisional order for working their own electricity undertaking even when a power company is on the spot and ready to supply their demands at a cheaper rate than they can reach themselves. Thus what is considered municipal enterprise frequently results in financial disaster.

It is surprising that when applications of this kind are made to the Board of Trade, they, until recently, did not take the trouble to inquire more fully into such an important matter before they gave their consent to what frequently turned out to be unremunerative expenditure by minor local authorities, but they are fortunately now exercising their authority by revoking a quantity of provisional orders applied for and obtained by the local authorities, owing to their having failed to commence the scheme themselves within a specified time, on account no doubt of the fact having been pointed out to them that it could not possibly pay, and which might have been discovered just as easily at the initial stage of the application.

The Local Government Board is applied to for loans, and an inquiry is held in the town concerned, usually by a retired engineer whose knowledge of electrical matters or even mechanical engineering details is often extremely limited. It would be more beneficial to the ratepayers if those were made by men qualified by actual central station and tramway experience,

to criticise the schemes put forward for their recommendation or approval, as if this were done, in conjunction with proper investigation in the first instance by the Board of Trade, the present unsatisfactory state of affairs in most of the municipal electrical undertakings would not exist.

TABLE I.—Municipal Electrical Undertakings.

Town.	Capital.	Gross Profits.	Street Lighting.		Motors.	Traction.
	£	£	Arcs.	Inc.	H.P.	H.P.
Manchester ..	2,199,690	166,207	53	..	11,000	11,068
Liverpool	1,718,713	136,490	189	28	5,190	9,000
Glasgow	1,119,048	99,879	814	..	6,500	..
Edinburgh ..	845,337	72,658	998	13	5,340	..
Leeds	817,304	56,790	247	..	3,900	..
Sheffield	804,527	42,982	..	..	3,600	..
Birmingham..	665,424	39,573	..	..	1,770	.
Salford.....	546,977	40,692	116	..	3,000	11,000
Brighton	522,437	38,335	372	3,260	1,080	2,400
St. Pancras..	460,366	40,316	461	..	315	...
	9,699,825	733,922				
Bristol	542,244	31,531	677	8	3,000	..
Nottingham..	417,272	37,226	160	..	2,000	2,100
Hampstead .	346,608	29,115	122	41	400	..
Sunderland ..	304,665	10,434	165	48	5,470	3,250
Hull	302,933	22,700	20	42	2,700	..
Hackney	273,897	20,224	293	..	986	..
Croydon	271,258	20,933	410	87	300	4,200
Norwich	261,548	20,141	16	9	1,104	..
Bolton	256,821	24,138	8	..	2,800	1,500
Leicester	245,131	19,884	.	..	700	3,000
	12,922,202	979,248				

Ignoring the less important of these, there are 184 in Great Britain and Ireland, the total capital expenditure on which amounts in approximate figures to 28 million pounds, 10 million of which are absorbed by the ten largest and a further 3 million by the second ten most important undertakings (see Table I.). The remainder or 15 million pounds has been spent by 164 municipalities, or roughly £90,000 by each on the average. As the total gross profits on the whole 184 undertakings for the last year's working was £1,127,000, and two-thirds of this was

credited to the ten largest and a total of one million to the first twenty concerns, the remaining £127,000 is left to divide amongst 164 undertakings on their £15,000,000 capital, or a return of less than 1%.

But of these sixty-nine undertakings, representing £5,000,000 capital expenditure, show a net annual loss of £70,000, after having provided in most cases for the interest on the loans and sinking fund out of the gross profits. But only in rare instances is a depreciation fund established, and where it exists it is not proportionate either with the capital expended or the life of the plant.

Comparing these figures with electrical enterprise as carried out by public companies, of which there are sixty with a total capital expenditure of £17,000,000, the gross profit is given as £2,000,000, or 11¾%. All but three of these companies, with a total deficit of £310, representing a capital expenditure of only £53,000, show a net profit on the year's working, whilst in addition to substantial dividends paid to shareholders, large depreciation and reserve funds are being built up.

This is done in spite of the fact that municipalities have the enormous advantage of the load and revenue derived from the street lighting, which in many of the towns is one of the most money earning branches of municipal undertakings, and accounts for their comparatively favourable balance sheet. In some cases private companies are entrusted with the supply of current for public lighting also, but not nearly to the extent of municipalities. In addition, seventy-eight towns provide the energy for the tramways from their municipal electric light works, whilst only nine private companies benefit in a similar way.

LOAD FACTOR.

The nature of the load is the all-important factor to be considered when the supply of electricity from central stations is

under notice. The most unremunerative source of supply is undoubtedly that derived from the lighting of shops, owing to their closing on the average at 7 p.m., with one day in the week off for the benefit of shop assistants, and it follows, that during the summer months, or practically half the year, no current is required at all.

Under this heading Manchester warehouses are almost on a par with shops so far as the demand is concerned, as at 5 p.m., their closing is marked by a sudden drop in the output at the central stations. But as these warehouses have cellars and offices which require illumination during working hours, their load factor works out somewhat higher than the ordinary shop. The load factor of residences, which are frequently shut up for several weeks in the year, is not a very great improvement on that of shops and warehouses, but their redeeming feature is that they use current when shops do not, which argument also applies in the case of places of worship.

The demand of these latter, however, is spoilt in this respect by choir practices and mid-week services, when their load overlaps the shop and private house demand. The theatrical houses, hotels, and public house demand for current is welcome for reasons readily understood, but the most profitable of all demands is undoubtedly the power or motor load.

As a typical instance, and to show the proportion of current used by the various classes of consumers, Edinburgh gives the following figures :—

Style of Premises.	Percentage of Consumption.
Shops	43·51
Houses	21·85
Hotels and Clubs	9·79
Works and Warehouses	7·64
Offices and Banks	5·64
Theatres	2·87
Police Offices and City Chambers	2·08
Public Halls	1·65

Churches and Mission Halls	1·63
Museums	1·35
Libraries	1·02
Schools and Colleges	·47
Fire Stations	·32
Public Clocks	·18
	100·00%

A further reference to Table I. will show to what extent profits are effected by street lighting, the motor and the tramway load. Manchester holds the record for the two last-named, which accounts for showing the largest gross profits of any electricity undertaking in the country. This is further explained by the following figures taken from last year's returns :—

Class of Load.	Units Sold.	Revenue.
		£
Private lighting . ..	9,939,381	159,300
Public ,, ...	81,032	675
Motors	4,739,992	23,260
Tramways	18,926,305	117,590
	33,686,710	300,825

These figures prove the importance of both tramway and motor loads, and which have raised the Manchester Corporation electricity undertaking to the premier position in this country as regards output and revenue. If the original scheme provided for electrically lighting eighty miles of main tramway-served thoroughfares were carried out, about 4,000 arc lamps would be required, but the author deals later on with facts to be considered before embarking on street lighting by electricity.

PRICE OF CURRENT.

The prices charged by the various electricity undertakings for the supply of current vary in accordance with the nature of the load, and a fixed tariff exists in only very few towns. On the face of it, it appears only equitable that consumers should be charged in accordance with their load factor. Thus, those with

a low load factor should pay the maximum rate, as it must be remembered that, whether they use the current or not, engines, boilers and other plant have to be provided and kept in readiness for them all the year round, and may be called upon to supply at a moment's notice, in the case of a sudden fog or thunderstorm. This is a contingency which occurs in many towns, especially in Manchester, where it is unsafe even during the summer to have very much plant down for repairs in case they are overtaken by phenomena of this nature.

Boilers have their fires banked, feed pumps are kept in readiness, and sufficient staff is on the spot to deal with such emergencies, and the sudden strain put upon a central station on such occasions can be imagined when the load increases within a space of a few minutes from a normal demand to a winter output and of eight to ten times the normal amount. It often happens that by the time the storm has passed away, the machinery has only just been sub-divided to its correct proportions and outputs, but owing to the demand suddenly dropping again, engines have to be shut down, causing the boilers to blow off and in consequence fires to be raked out and the station got back to its summer garb of working.

Although the additional revenue on these rare occasions is considerable, it is doubtful whether it covers the cost, if all the mentioned facts are taken into consideration. To provide against contingencies of this kind, and to safeguard the interests of electricity undertakings, the maximum demand indicator was introduced, by which two rates are charged. The first charge is intended to cover the standing and capital charges, if the consumer calls upon the supply works for his maximum demand for one hour per day. The second charge covers the works' costs and profit.

The advantages of the system are apparent, as the consumer with long burning hours reaps the benefit, but its complication,

especially to the consumer, and the necessity of providing special apparatus for recording the maximum demand, has brought other methods of rating into existence, by all of which, however, the main principle of encouraging the profitable consumer is adhered to. For lighting current the price of 5d. per B.T. unit is considered the maximum, whilst for motive power purposes the low price of $\frac{5}{8}$d. per unit has been quoted by power supply companies.

MOTOR LOADS.

The electric motor is now developed to such an extent that with the reduction in the price of current to the figures quoted, it can compete against gas engines, when all its advantages are taken into consideration, such as saving in capital expenditure, floor-space, maintenance and running costs, easy manipulation and constant or variable speed, as may be wanted. Electric driving is now resorted to for almost every conceivable purpose, from the dentist's drill upwards. The charge for current is considerably reduced as an acknowledgment of the importance of this branch of central station working, whilst sliding scales have been established, thus proportioning the price of current to the demand of the consumer. Schemes for hiring out motors at reasonable rates have been established with gratifying results, so much so, that internal combustion engines are in certain cases being replaced by this new rival. Too much importance cannot be attached to the selection of an electric motor, as cheap ones invariably cost more in the end, owing to the frequent repairs and overhauling they require, but especially their low efficiency Several instances have come before the author's notice, in which a low price or second-hand motor has been installed and thrown out after a few months' working, on account of the increase of working expenses as compared with other methods of driving.

The fixing of a motor suitable in all respects, especially as regards size, by not being either too large or too small, has

always remedied the complaints, and although no skilled attendance is necessary, it is always advisable for a periodical examination and test to be made to ascertain whether any deterioration has taken place in the machine and controlling apparatus. A good motor is first recognised, when no sparking takes place at the brushes at all loads, but also when the temperature of the windings does not exceed such as will allow leaving the naked hand on the coils. For variable speed working, such as printing machinery, the electric motor is now almost indispensable.

STREET LIGHTING.

It cannot be claimed that arc lighting as at present installed in public thoroughfares is an unqualified success. The improved methods by which gas and petroleum are used to their full advantage at a minimum of cost has resulted in competition for street lighting effects to become most keen, and many are the reports of gas and electricity officials on the merits of their own particular system in comparison with their competitor. The illumination from arc lamps is generally obtained by placing them farther apart and higher than the gas lamps. The distance dividing the arc lamps, as well as their height, is arranged so as to allow the rays of one lamp to meet and intersect those of the adjacent ones.

The intense glare of an arc lamp of high candle power, which is often subdued at a great expense of energy by using globes of varying opaqueness, must not intrude upon the direct line of vision of pedestrians. The same quantity of illumination from gas or petroleum lamps for a similar area is, however, obtained from probably twelve or more burners at less height from the ground, thus more effectively striking the eye of the general public, and, therefore, appearing to give a better all-round lighting effect. To compete against this, electric lamps of equal candle power to the clusters of existing gas lamps should be

placed at exactly the same heights and positions, but efficient small current consuming arc lamps have still to be designed to obtain these results, and incandescent electric lighting has so far failed to accomplish this with the same amount of success.

The cost of carboning and keeping arc lamps in thorough repair, without which their delicate mechanism will not operate, as well as that attached to supplying and maintaining incandescent electric lamps, is heavier than the upkeep of incandescent or high-pressure gas and petroleum lighting, and there are still opportunities for the inventor to develop the design and successful application of apparatus connected with electric street lighting. The Nernst Tantalum and Osmium electric lamps have effected considerable improvements of value, having succeeded in reducing the current consumption per candle power, and in intensifying the light at one point without producing the glare and colour of the arc lamp.

But the initial cost and maintenance of these lamps is heavy and such as will not compare favourably with gas lighting. As will be seen, however, from Table I., many corporations, especially if they do not own the gas undertaking, carry out a large amount of street lighting, quite independent of both the financial and practical results. In Edinburgh, for instance, nearly 1,000 arc lamps are installed for street lighting purposes, which represents 2% of the total possible load on the generating station, but from which the revenue is £11,000 per annum, or 10½% per cent. of the the total revenue of the undertaking.

The units consumed on public lighting is also about 10½% of the total units supplied. In the City of London the main streets have been illuminated by means of arc lamps for several years, current for the purpose being taken from a supply company. The contract has, however, recently been terminated, and gas lighting is again being resorted to.

TRAMWAYS.

Electric tramways, of which no less than 1,800 miles exist at the present moment in the United Kingdom, have probably made the largest progress of any branch of electrical engineering during the last few years, the many advantages they possess over horse, steam and cable traction both in comfort, speed and cheapness, being responsible for their enormous success, inasmuch as three times as many passengers are carried now than by the old systems. We cannot, however, claim the same progress realised by either our Continental neighbours or foreign countries, owing chiefly to our Board of Trade restrictions or the petty jealousies of local authorities. Tramways should not only serve townships and outside rural districts many miles from the source of supply, but the various lines belonging to many districts, whether they are controlled by local authorities or private syndicates, should be linked together in such a way that it is possible to travel almost from one end of the country to the other.

Long distance services are now making considerable progress in England, and it is to be hoped that tramway enterprises will not stop until it is possible to travel from John o' Groats to the Lizard. Since the day when the single reduction traction motor, the series parallel controller and the overhead trolley were adopted in England as standards of tramway practice, practically no improvement has been made until quite recently in the equipments except in the simplest details.

The tramway world has now before it the automatic regenerative system, the main principle of which is the use of a shunt wound motor instead of a series motor, it being well known that such motors will act as generators when their back electro motive force exceeds the electro motive force of the line. It was impossible to use shunt motors for electric traction until they were so far improved as to have a fixed line of commutation, and very

great difficulties had to be overcome in adapting both the motor and the controller to the existing conditions of electric traction.

The first attempts were made with motors coupled permanently in series, which, however, reduced the speed up severe gradients. The development of a series parallel controller and the addition of a few turns of series winding to the shunt winding of the motors have removed this objection, whilst the tractive effort and consequently the accelerative power are not diminished in any degree, but on the contrary somewhat enhanced. The principle advantages of this method of control are:—

1. A car has the full power behind it, even when travelling at very slow speeds.

2. The braking effect is superior to that obtained with any other arrangement.

3. The saving of electrical energy, which varies according to the nature of the road from 10% on dead level line to 35% on a hilly line.

4. The reduction in the wear and tear of the brakes, wheels and rails.

The last item is one deserving the serious attention of tramway undertakings, as the question of allowing an adequate amount for depreciation on these items does not appear to have been given sufficient consideration when dealing with the annual balance sheet.

The Birmingham and Midland Tramways Company, has carried out interesting tests on the Yardley route, which is about four miles in length. The savings effected in repairs and maintenance amounted to 44% per car mile, whilst the current consumption was reduced from 1·24 to ·97, or ·27 units per car mile. These figures were obtained after running the two types of cars for four weeks each, with a mileage of 65,000 or 845,000 per annum. The money value of the saving in electric energy only, on the basis of 1½d. per unit, amounts to £1,214. 13s. 9d.

per annum, or approximately £50 per car per annum. Regeneration was amply illustrated by the fact that three sets of generating plant was sufficient to maintain the service with regenerative cars, but four sets were required when the line was equipped with ordinary series parallel cars, all the cars being exactly alike.

Many attempts have been made to replace the overhead system by one avoiding what is often considered a desight and danger, when conductors, span and guard wires are suspended in the air. Several surface contact systems have been designed on the principle, that current only flows through that section of the line over which the car is passing at the time. This is either effected by a series of knobs, which are mechanically depressed or raised by the weight of the car itself passing over the mechanism actuating switchgear, or by magnets fixed under the cars, which by drawing up contact pieces or plungers, collect the current. At Wolverhampton the Lorain system has been adopted, in which the electricity is picked up from studs laid between the track. The cars are fitted with skates and by means of electro-magnets, the studs are attracted, which close the circuit to the motors. The danger in this system is the non-releasing of the studs, thus leaving them charged with current, and the result of making contact with them and the rails or even the surrounding earth on a wet day would be to transmit the full difference of potential to the object or subject.

In all such systems the extra prime cost, as well as the additional risks of breakdown, due to the careful insulation required and a complexity of switch gear on the track are outweighed by the advantages. Leakage of current cannot be prevented either with this or the open conduit system, which has developed considerably during the last few years, and the most notable installation of which is the one carried out for the London County Council. The open conduit is laid centrally

between the rails, only a slot, into which the car plough is inserted to collect the current, being visible. The rails rest on cast-iron yokes fixed 3ft. 9in. apart, the conduit chamber being 17in. deep by 14½in. wide, in which rest the insulated conductors.

The careful precautions which had to be taken for keeping the conduit thorougly drained, in addition to the expense of removing mains of all descriptions and other obstructions, has rendered the whole construction very costly, being a total of £14,500 per mile of single track, or more than double that of the overhead system. From an economical point of view, therefore, neither the existing surface contact or conduit systems can compare with the overhead system, but if safety and reliability in working could be guaranteed, even a considerably higher prime cost would undoubtedly be disregarded by towns desiring to preserve their sky line for a full view of the ocean or their cathedrals.

This could also be obtained ideally by accumulator cars, but the cost, weight and heavy maintenance charges have proved the impracticability of this method, and the inventor has ample opportunity for exercising his talents to produce a perfect and invisible electric surface tramway system.

RAILWAYS.

In America the pressure of transmitting electricity in large quantities has reached a maximum of 60,000 volts for a distance of 154 miles, and 40,000 volts in Italy, where several hydro-electric installations are successfully working for supplying current for main line railway working, and in which branch of electrical engineering our English railway authorities are but just commencing to recognise the importance.

In London and Liverpool, local and suburban traffic drawn by steam locomotives has been superseded by electric machines, and the results in the Mersey Railway Company prove that the

change is appreciated by the public, as 25 % more passengers are carried now than formerly. The electrification of the London Underground Railways has been recently accomplished, and the Metropolis now boasts of more than half of the total mileage of electric railways in this country. The latest development in this direction to be recorded in England is the electrification of a portion of the London & Brighton South Coast Railway's suburban line, for which the single phase system has been adopted.

In America and Germany several lines are running satisfactorily on this principle, the favourable points as compared with continuous current being :—

1. Higher initial pressure and consequent saving in copper.
2. Absence of sparking commutators on the motors.
3. Freedom from troubles arising through electrolysis.
4. Easier distribution by means of static transformers, these requiring little or no attention.

It is interesting to note that the single phase system came into vogue for lighting purposes, and was generally favoured about fifteen years ago, when the maximum voltage of incandescent lamps was 100, and in many cases only 50 volts. This naturally meant heavy copper feeders and distributors if low tension current was distributed direct from the generating station.

A maximum pressure of 2,000 volts was used for the primary supply, and each consumer had a converter fixed on his premises for reducing the pressure. With the advent of the higher voltage lamp and the electric motor, continuous current replaced the single phase supply, but as undertakings increased their areas of supply, the high pressure alternating current once again came into favour in the shape of the two and three phase current already mentioned.

An experimental railway at high alternating pressure was equipped at Berlin and a speed of 100 miles per hour was attained, thus proving the possibility, if not the practicability, of high speeds on railways. The single phase system only requiring one overhead conductor as against two or three for multiphase systems, and the difficulty of designing an efficient single phase motor having been surmounted, represents now the latest stage of the development of electricity for traction purposes. Our main line railways are slow in following the lead of foreign countries, where great progress has been made in electrification, and it is difficult to understand the want of enterprise shown by those responsible in England for this most important opportunity of electrical development. The capital expenditure involved by the change from steam to electric traction is necessarily heavy, but not prohibitive and the experiments on local railway lines are in many cases being forced by the competition of the electric tramway service. As no engineering difficulties present themselves, it is to be hoped that our large English railroads will keep pace with modern progress, and by electrifying their main line traffic will continue to hold the world's record of perfection in railway working.

POWER SUPPLY COMPANIES.

A combination of unremunerative prospects for small electricity undertakings and the development of the electric motor for the driving of factories, corn and cotton mills, engineering workshops, the hoisting, traction, lighting, etc., in coal mines or the linking up of tramway enterprises, has resulted in a supply of current in large quantities at low rates being given by power supply companies. The generating station is built close to the coal pit and every natural advantage is seized to establish low works' costs. By generating at extra high pressure, which is converted at various centres to one suitable for the purpose, large areas can be served. Two or three phase current is sent

out from the central station and converted to either low tension alternating or continuous by means of motor generators, rotary convertors or static transformers.

Many urban authorities are wisely handing over their concessions to power companies, thus relieving themselves of the responsibility of installing their own generating station and obtaining their current in bulk at wholesale price. They only have to distribute the electricity and as this can be done, owing to the low initial price charged them, at a profitable figure, the return on the capital expended on cables and meters is ensured. Even if mills, mines and factories are able to generate their own supply (owing to their not requiring to provide the distribution expenses of a power company) at a slightly lower figure, the convenience of always having the power at their command for light and heavy loads, without having to meet heavy capital expenditure for engines, boilers and the buildings to house them, is recognised by their owners.

The South Wales Power Company were the first to appreciably enter the lists of this new enterprise and are now supplying energy over an area of more than 1,000 square miles. At their chief generating station an initial pressure of 11,000 volts is utilised, this is the maximum so far employed in this country and which is also adopted by the Cleveland and Durham and Clyde Valley Power Companies.

CABLES.

In every electricity undertaking of any magnitude, the cost of the feeding and distributing cables is one of the chief items of capital expenditure, which accounts for the higher costs and rates of supply as compared with private installations. This can be considerably reduced if bare overhead conductors are used in place of underground insulated cables with their accompanying troughing or ducts, excavation of the roads, making good, etc.

The interest on the capital as well as maintenance charges can be saved, if overhead current transmission lines for either lighting, power, tramways or railways are permitted, and an impetus will be given to the general use of electricity, and especially the inter-urban linking up of our tramways, which will at least bring it into line with foreign practice. Unfortunately the Board of Trade does not encourage enterprise towards achieving this very desirable economy any more than they have done for the last twenty-five years on other subjects relating to electric supply.

Their action has retarded progress since their first regulations were issued in 1882, and although these, after pressure from influential quarters had been brought to bear upon them, have been revised, but not to the extent that periodical progress demanded, they do not prevent serious accidents, and are frequently the means of needlessly increased capital expense. It is only comparatively recent that extra high tension—*i.e.*, over 3,000 volts, has been universally permitted, but still with all manner of restrictions.

This advance was rendered necessary by the adoption of high-tension three-phase current, which has for a time superseded the high-tension single-phase method of supply and distribution, when static transformers were fixed in private houses or sub-stations to reduce the initial pressure to 100 volts for general use. This again has been lately increased to 200—230 volts by permission of the Board of Trade, thus enabling the cables of supply undertakings to carry four times the output of current. Several large electric power schemes now under construction would have been commercially impossible, unless the Board of Trade had given way to the demands of the promoters.

In a few instances, notably the North and South Wales power schemes, overhead transmission has been permitted, and the importance of this concession cannot be over-estimated on feeder

cables, the pressure being 11,000 volts, as the outlay is less than one-half that of an underground cable system. Further difficulties are introduced by local authorities and land owners having also to give their consent to overhead cables, as they invariably consider anything of an electrical nature dangerous and therefore prohibitive. The æsthetic and sentimental point of view is also introduced, and not even the payment of handsome wayleaves is sufficient incentive for permitting creosoted poles carrying the wires to spoil the sky lines.

Continental and American practice shows neatly designed lattice designed uprights supporting as many as nine cables for spans of 100 to 150ft. over fields, gorges and valleys, a skull and cross bones painted white on a black ground on each post being sufficient to prevent curious people interfering with the structure and its appendages.

It is claimed that a still further reduction in the cost of both underground and overhead cables can be effected by utilising aluminium instead of copper, whilst several systems are now in use in which bare copper is laid underground in earthenware or ferro concrete troughs, which are filled up with a plastic insulating compound, all of such improvements assisting materially towards still further promoting electrical development.

ACCUMULATORS.

Accumulators now play an important part in smaller central stations, especially in conjunction with boosters, for steadying the supply pressure on both lighting and traction systems, and it is somewhat surprising that their manufacture has not shown the same marked progress as other electrical plant. Competition has certainly resulted in reducing their prime cost, and important improvements have taken place which increases both their life and output. They are now made more substantial, to avoid troubles arising through the buckling of plates and the

stronger sections adopted, enable makers to guarantee all round results with lower maintenance costs. Their efficiency, however, still leaves much to be desired, as a return of 70% of their charging current may be considered a good average.

Much has been said and heard about the new Edison cell, which however does not appear to exist beyond the experimental stage. The principle of this accumulator is the use of plates, made of thin sheet steel, nickle plated, instead of lead. The pockets on the positive plate contain nickle peroxide and those of the negative plate, finely divided iron, whilst the electrolyte used is a 20% solution of potash, instead of the usual sulphuric acid. The result of this combination is to reduce the weight of the whole accumulator very considerably and also enables it to be charged quickly and discharged at very heavy rates, without damaging the plates. The tests available show however that the efficiency is no better than that of existing accumulators, and we, therefore, have still to look forward to fresh discoveries in this particular branch of electrical apparatus before the very desirable solution of the problem of storing electricity both at a moderate capital outlay and a considerable reduction in the working costs and maintenance is realised.

Their usefulness cannot be denied, and as the one advantage that gas can now claim over its rival electricity is that, relating to its capability of being stored in large quantities, although in its case it is certainly more a necessity than a luxury, the large number of patents filed during the last few years for secondary batteries show that inventors are at work in the hopes of discovering the secret of success in this direction also.

COLLIERIES.

A further adaptation of the regenerative principle is used with great success on colliery work by the Ilgner system, when hoisting or lowering the cages into the pits. It must be remembered that when hoisting gear is driven electrically

either from the colliery's own generating station or from a power company station, rushes of current and consequent fluctuations in the line must be avoided. These difficulties are satisfactorily met by running a motor coupled direct through a heavy flywheel from the main dynamo. The hoisting motor is a shunt wound machine, whilst the generator is separately excited to obtain the full range of voltage. When commencing the hoist the exciting current of the generator is reduced, and the torque being proportional to the current, and the voltage being at zero when starting, the motor current is at a maximum. The excitation of the generator is increased gradually, which raises the E.M.F., but decreases the amperes on the hoisting motor, as the cycle of raising or lowering the cages proceeds, thus keeping the total energy constant. The heavy flywheel, which is the secret of success on this system, is designed of suitable dimensions to enable it to store up or give out the compensating kinetic energy, which the circumstances demand. Perfection in design has insured this being done to the exact amount required and so that the output of the motor driving the generator remains constant.

When one cage is approaching the top of the shaft the second cage is nearing the bottom, and the impetus of the motion (especially if the cages are unbalanced), together with the stored energy of the flywheel converts the shunt wound hoisting motor into a generator, and by reducing the exciting current of the generator, thus causing its E.M.F. to drop, whilst that of the motor has remained constant, the action of regeneration is not only an efficient brake through the retarding effect, but returns current through the motor generator (now converted into a generator motor) into the source of supply.

In the case of a failure of current from the main source, the stored energy is found sufficient to complete the hoist. The many other applications of electricity in coal mine working

include lighting, haulage, pumping, ventilating, coal cutting, washing and screening, rock drilling, etc., all of which present advantages over what must now be considered other antiquated systems. These did not allow for a central distribution of power with its resulting economies and flexibilities, absence of long lengths of heat radiating and leaking steam pipes, and especially a safe system of illuminating the dangerous pits and passages.

Electric traction and haulage alone in a mine has not only doubled its output, but reduced the cost (as compared with horse haulage) from 4½d. to ½d. per ton. It has been found that the whole of the capital expended on the electric conversion of a coal mine was repaid in about three years by the various economies introduced and other advantages realised.

MILLS.

Although volumes have been written, and might still be compiled on the subject of electric driving in cotton mills, and experiments have been carried out with great success in this direction, the conservatism of mill owners has still to be broken down, and a large sphere of operations is open in this branch of electric work. Electrical engineers only should be responsible for drawing up specifications and superintending the necessary work for the electric driving and lighting of mills, not only to minimise the risk of fire, but especially to obtain the correct plant, and one suited to the requirements of each individual case.

The old-fashioned shafting, either belt or rope-driven, should not be adhered to with such conspicuous tenacity, and we must again refer to experience obtained in other countries to prove that electrical driving is more economical, besides realising larger outputs, than mechanical driving. However carefully shafting is arranged and the drives designed, the frictional losses may still amount to as much as 40%. The steady running

required for spinning and weaving, as well as the variable speeds necessary for bleaching, are met by electricity exactly. Constant speeds can be assured by installing alternating three-phase motors, whilst direct current motors are capable of being driven at speeds of any variation.

Apart from the saving in building space, the reduction of running costs and the application of either constant or variable speeds as may be required, electric driving in mills, by its flexibility and simplicity, guarantees increased outputs due to higher speeds, and a considerable saving in the cost per pound of yarn turned out. By subdividing the main source of power into say three units, one being spare, freedom from breakdown is insured, and at the same time portions of the mill can be run during overtime without spoiling the load factor of the plant.

The upkeep of expensive belting and ropes is avoided, troubles due to long lengths of shafting and heated bearings are prevented, and the whole of the machinery can be kept running to its full advantage. It is only during the last twelve months that mill owners have realised the practicability of this application of electricity, and mills are now building, electrically equipped throughout. When the working results are published, they cannot fail to impress the textile world, and further developments on a large scale may undoubtedly be expected in the industry.

CONCLUSION.

The advance of electrical engineering during the last 12 years disqualifies that favourite quotation "electricity is still in its infancy." The progress made in the science has almost awarded mechanical engineering with that distinction as electrical working has called upon engine builders, boiler makers and manufacturers of accessories, such as feed pumps, superheaters, economisers, mechanical stokers, water purifiers, cooling towers,

condensers and even piping, valves, etc., to produce highly efficient and mechanically strong articles only.

The development and improvement of the steam engine, turbine, water-tube boiler, etc., has been equally marked during the same period, and it cannot be gainsaid that the engineering world generally has benefitted by the growth of the infant. The new principles evolved by the late Mr. P. Willans, and followed up by other engine builders, have given the world a mechanically and thermally efficient high speed prime mover, with almost perfect governing and freedom from vibration. The introduction of superheat with a temperature of 500 – 550° Fah. at the engine stop valve has still further reduced steam consumption to 10lbs. per IHP hour and increased mechanical efficiencies to 95%.

Reliable turbines of both horizontal and vertical design are now on the market, thanks to the unswerving efforts of the Hon. C. A. Parsons, and the care and patience exercised by the designers, producing rotaries able to cope with loads of any magnitude or variation. The internal combustion engine, whether driven by town's or suction gas or oil, of which large quantities are turned out for driving dynamos of smaller outputs, is now built with the main object of obtaining economic results, and ensuring freedom from breakdown. The Diesel Oil engine claims a result of over 11BHP for 1d. per hour, whilst the gas engine can give 10BHP for 1d. per hour, gas being obtained from anthracite coal at 22/- per ton. Sudden and heavy demands and overloads upon steam raising plant in case of fogs have called for boilers to meet the arduous conditions, and water tube boiler makers have risen to the occasion and provided plant which fulfil the conditions both mechanically and efficiently.

The large quantity and by far the majority of central stations fitted with water tube boilers of various types, is sufficient evidence of the aptitude and excellence of this type of steam

raiser, which, when fitted with complete and efficient automatic stokers and run in conjunction with superheaters, can show such proportionately high evaporations and low coal consumption. The claims of makers of automatic mechanical stokers have been justified, and the prevention of smoke, an even and constant and economical supply of fuel and as nearly as possible complete combustion, are now assured.

Higher piston speeds and the development of prime movers, especially turbines, have demanded greater steam pressures, and as, in order to obtain maximum efficiencies, the steam must be dry, superheaters independently fired or fixed in the flues or boiler brickwork, have now become a necessity. Although steam superheated to 650° Fah. is at present used chiefly abroad for driving slow-speed horizontal engines, the difficulties connected with such high temperatures are now realised by English engine builders and gradually being overcome.

The principle of absorbing waste heat and gases is carried out still further by feed water heaters and economisers, and vast improvements in these heat-saving devices can be traced to electrical development. The steam consumption of feed pumps has not escaped notice, efficiencies of 95% and an output of 120lbs. of water per pound of steam being guaranteed, whilst other auxiliary plant belong no longer to the steam eating class.

The design of jet and surface condensers with their accompanying pumps and cooling towers has been revolutionised, vacuums of 1in. below barometric pressure being now requisitioned. Large central stations have found the cost of condensing water a serious item to deal with in their returns, but the installation of cooling towers has effected economies which enable town's water to be used with only a loss of 2½% per cent. through evaporation and an absorption of power not exceeding 1½% of the total IHP the plant is serving. These developments are

the result of demands made by electrical engineers, and, by benefitting them, all have contributed towards the success of electricity for lighting, power and traction purposes, and at the same time have brought all engineers nearer to solving the problem of producing 1HP. from 1lb. of coal.

DISCUSSION.

The PRESIDENT (Mr. Robert Matthews) in declaring the discussion open remarked that the Paper was very free from exaggeration, and was quite a model in its way for electrical engineers. It would, he hoped, result in a good discussion amongst members connected with electrical engineering works.

Mr. ALFRED SAXON said that he wished to give every credit to the author for his very valuable paper. Mechanical engineers owed much to electrical engineers for stirring them up in many ways during the past few years, but he thought that electrical engineers were too much inclined to advocate electricity for every purpose, whereas for some of the uses to which electricity had been applied, and had been recommended to be applied by the author, it was not necessarily more advantageous, economical and cheaper than other existing forms of driving. He had recently been speaking to the director of a firm in Salford who had for some time been driving a portion of their concern electrically, the machinery driven consisting of ring frames and winding and warping. For current alone the firm paid on an average about 20d. per week per IHP for about 160 IHP with the cost of current at ½d. per unit, and a working week of 55½ hours.

He had on the other hand obtained particulars of the costs of steam engines running which varied from 4d. to 6d. per IHP for a week's run of 55½ hours.

With regard to the question of driving mills electrically, the author might have waited for some definite results before declaring himself, and the conservatism of mill owners on this question had been mentioned. The owners of mills in this country however had been justified up to the present in their conservatism, because they had no proof on a large scale that a mill could be driven cheaper by electricity than by the various methods of mechanical driving in use. The author had stated that the old-fashioned shafting, either belt or rope driven, should not be adhered to with such conspicuous tenacity, and that we should refer to experience obtained in other countries to prove that electric driving was more economical, and that however carefully shafting was arranged and the drives designed, the frictional losses would still amount to as much as 40%.

Anyone who had compared recent records with regard to friction would know that statement to be altogether wrong. The engine and gearing friction combined of a modern cotton mill averaged not more than 20%, and he knew of engines only where the friction had come out to only 7½%. In a paper he had read before the Association some 10 years ago, the average of engine and gearing friction did not come out to more than 25%. At the present time with ring oiling pedestals and shafting properly levelled and fitted up in new mills the author's figure of 40% was undoubtedly wrong.

A short time ago he had made a suggestion to the Council that similar statements to that which the author had made should be tested by a committee of the Association, so that reliable figures would be available on which to work. On the steam engine side of the question he would be willing to spend the time, and to get mills placed at disposal for such investigations.

Mention had also been made that by the adoption of electric driving the upkeep of expensive belting and ropes was avoided,

troubles due to long lengths of shafting and heating bearings prevented, and the whole of the machinery could be kept running to its full advantage.

These troubles were quite imaginary. His firm had geared up a cotton mill 20 years ago, and not a single step had been renewed in the whole of that time: and if enquiries were made from rope driven mills that had been erected during the last 10 years it would be found that those troubles had been rare.

The long lines of shafting had not been dispensed with in the electrically driven mill at Pendlebury; quoting from a specification which had been sent to his firm to tender for the shafting required for this mill, he mentioned that this specified 2152 feet of shafting and 77 pairs of flanged couplings to connect these various shafts together. This *shafting* was for a mill to be driven electrically. Also there were specified 389 strap and rope pulleys, and 95 pairs of guide or gallows pulleys. That did not look like shafting and belts and ropes being dispensed with. The value of the gearing for a cotton mill of this size was about £3,000, in addition to which there was the cost of the motors, and it shewed that with this system of electric driving in cotton mills they were far away from dispensing with the line shafts. The only thing that had been done, which was a step undoubtedly in the right direction, was that the speed of the line shafts was increased considerably and the size of the shafting correspondingly reduced, the size of the drawing pulleys had also been reduced; these were points in favour of electric driving but were also possible of attainment in a mechanically driven mill.

Electricity in some branches of the cotton trade might be the correct thing, say in branches where very fine spinning was required; and where the cost per lb. of produced yarn was exeeedingly high for the higher classes of yarn it might be suitable, but in his opinion the cost of the installation and the

cost of upkeep in connection with an electrically driven mill would make it impossible for the coarse cotton yarn to be spun by electric means. He had made enquiries from a gentleman who was one of the promotors of the mill at Pendlebury, the only spinning mill which was run electrically in this country, but could get no information from him. He had also been through an electrically driven mill at New Bedford when visiting America and there also could get no definite information. The only information given in each case was that the cost was about the same as for steam driving, but no particulars were divulged.

He also knew of a mill at Kearsley, near Manchester, which was being erected to be driven electrically, the current to be generated on the mill premises by steam turbines, and the only guarantee the directors had obtained was that the mill should run as cheap as another mill in the neighbourhood driven by steam.

In conclusion he again thanked the author for his paper.

Mr. Jas. G. Walthew stated that the accumulator system of driving cars was undoubtedly the ideal system, as it got over all the difficulties that obtained in the overhead traction and the underground systems. He wished to know, however, whether a combination system was not sometimes advisable. In several towns on the Continent, as in the case of Brussels, where they had long tramway routes through open country, or along streets without a great number of turnings, they used the overhead trolley system, and when they came to very crowded thoroughfares, storage accumulators on the trams were then used, from which the trams derived their motive power, thus dispensing with all overhead or underground equipment. That seemed to him a very good plan indeed, but he wished to know whether it was an expensive plan to adopt.

With regard to electric haulage for collieries, he did not know whether the author would recommend this system for a good many collieries in this country. In Germany, where the Ilgner system which had been mentioned was used, as also in South Africa, the depth from which the coal had to be lifted was very much in excess of what it was in this country. He therefore questioned whether the electric method of obtaining coal in this country would repay the cost when it was considered how cheaply coal could be got here. Some of the German and South African mines were 5,000 or 6,000 feet, and two-stage haulage was adopted; whereas with mines around this district it was a fairly deep one if it were 500 or 700 yards deep. There was a big difference therefore between say 2,000 feet as representing depth of English coal mines, and 6,000 feet as representing South African mines. Such being the case in this country coal could be obtained at a very low cost; therefore, he did not think it would be at all advisable to advocate electrical methods for obtaining coal in this country.

Mr. Cook interposed with the remark that he thought Mr. Walthew was wrong in the matter of the depths of mines in England, as the Ashton Moss Pit was 1,300 yards deep, and there were other deep ones.

Mr. J. G. Walthew continuing, said that he was not taking any particular instances, but was only speaking of the average instances of the low depths at which coal could be got in this country as compared with Germany and South Africa.

Mr. W. H. Cook stated that in his opinion there was a great race running between electricity and steam, and apart from the question as to whether mill owners were conservative or not, he thought they ought to be very careful in leaving the old-fashioned steam drive. From observations he had made on the

Continent, they were undoubtedly making a lot of progress there.

Mr. Stubbs and himself would shortly present a paper on the textile industry, and in this paper they would endeavour to give a record of an Italian mill which would go into the matter of costs, &c., if the mill authorities would give the information. He had asked the English electrical engineers for the information, but had been disappointed with the replies; they either did not know, or would not give the information.

Another matter which appealed to him was the comparisons given of different stations. As a past official of the Manchester Corporation the author had no doubt put the best phase on the Corporation side; but the latter half of Page 65 struck him (Mr. Cook) as being most damaging against municipal trading. If this was a correct statement, and certainly it had not been put specially against the Corporation, people should rise and take more interest in the subject. It was amazing to think that only 1 % was made on the capital outlay of municipal installations, whereas private firms could make 11 %.

Another interesting matter was the mention of cables, and the English Government not allowing overhead cables to be used, although they were allowed abroad.

Some 12 years ago he was surprised when going by train from Milan to Valle Seriano to see a cable $\frac{3}{8}$in. or $\frac{1}{2}$in. diameter, mounted on poles placed at the roadside. On enquiry he was informed that turbines were fixed against a mountain torrent some miles away, and high phase electricity was generated and carried along the roadside to all the villages near, and some mills were driven at a distance of nine miles away.

Mr. Z. Tetlow said he was pleased that the author had mentioned the question of apprentices, and agreed with him that too much of this was being done all over the country. He was

glad to know recently the L. & Y. Co. were giving privileges, perhaps through the efforts of the Manchester Association of Engineers and Victoria University, for a certain number of their apprentices to give two afternoons per week to technical studies, and were paying their wages for this time.

Respecting Municipal electric supply and electrical and hydraulic undertakings; he thought these were for the benefit of the people, and not for money making concerns, but there was no doubt large profits had been made in many towns, and he thought everybody was benefitted by tramways, and by the electrical and hydraulic undertakings being taken over by the Municipal and District Councils. He stated that in his opinion the motor bus was coming to the front, and in many cases he thought would oust the tramways from their position, especially in towns with very narrow streets, and where the traffic was congested.

As regards electric railways, the L. & Y. line, from Liverpool to Southport had been running for some time. The cost of working when allowances were made for the depreciation of the more costly plant was higher per train mile run. They were quite satisfied as they had given a very largely improved service to the public, and they were contemplating some additions to the rapidly growing traffic. They had carried very large additional numbers of passengers over the electrified portion of the railway, especially for short distances, and the system was running smoothly and well.

The cost of electrifying the line was something like £350,000, but since then additions had been made by adding battery stations so as to get over the difficulties of the traffic through the busiest parts of the day. Of course the Company were fortunately in a position to use the displaced rolling stock on the rest of the line, or the above total would be increased by the value of the stock so displaced.

No figures were available as to the cost as against steam *v.* electric trains, but there was no doubt the up-keep of the permanent way on the electric railwav was very large. They had recently coupled up with the electric the Liverpool Overhead Railway at Seaforth and were exchanging traffic with that Company.

He wished to know if the author could give any information—as he had a large amount of practice—as to Lancashire boilers and water-tube boilers, as to up-keep, etc., and also about the "Parson's," "Curtis," and other turbines for generating power stations. That was, if he had any preference for any of them.

Mr. Joseph Parry said that some years ago the Glasgow Corporation reduced their fares by about one-half, in order to bring the profit down to the 1% mentioned; they really made a profit and disposed of it to each one who rode on the cars. Comparison therefore between Corporations and private concerns as usually made was not fair.

No mention had been made by previous speakers respecting municipal electric lighting. He lived in Heywood, which was supplied with electric light by the Corporation; but the latest development of electric lighting in that town was that many of the shopkeepers had taken the electric light out, and had put in gas, the inverted incandescent mantle giving a better light at a less cost.

Mr. S. H. Rowley said that the advantage of electrical driving was gained more in the aggregate of savings in incidental details. He had lately substituted a number of motors for belt drives, and a direct result of this being that things had begun to be looked into more closely. For instance, ammeter readings recently showed undue load on the engine; this led to immediate investigation, and a hot bearing was found. Some time back he had put down an expensive special machine tool, motor driven, direct coupled. In the construction of this

machine there was a certain amount of gearing which was covered in, and therefore could not be seen; there were a number of bearings and so on. It was started up and ran well for a time, and then the fuse went; a new one was put in, but a short time after that went. This led to an ammeter being put in circuit, and it was found that it showed considerably above the load necessary for the cut; it was investigated, and instead of the load the trouble was found to be due to a hot bearing. If that tool had not been driven electrically the overload would not have been noticed, and gulling of the bearing would have resulted. The aggregate of these savings in twelve months was the point often lost sight of, but it was one of the most important factors in the consideration of the economy resulting from electric driving.

Mr. Thomas Ashbury said that he knew a large firm in this country who decided to throw out all their steam boilers of the Lancashire type, and all their reciprocating engines, and to make a generating station in the centre of their works; they put in three of the largest size of Babcock & Wilcox water-tube boilers, and a complete plant for electric driving; and from that central generating station they now had running in various parts of their works about 125 or 130 motors of various sizes and kinds. The experience of that firm was, firstly, decidedly in favour of generating their own electricity, and *not* taking the town's supply, either for lighting or for power, and secondly, they found it to be economical, not so much perhaps in the question of money, as it was in the immense advantage they had in being able to run any section of their works, or any large tool in the works, independent of others, during extra hours. One good point in connection with that works was that they had sufficient accumulators in reserve whereby they could run the whole night through a considerable number of the machines to

manipulate break-down work, and this was a very great advantage.

The matter brought before them in the paper was one of intense interest to all, it took a broad view of the subject, and whilst some would no doubt be disappointed, it took a general survey of the aspects of the electrical developments of the present day.

In England we were following hard after the achievements in the electrical developments of other countries. Taking America, he knew one firm who had no less than 42,000 HP of electric power, and this was being used day by day no doubt to great advantage.

Respecting the question of overhead conductors or leads, in this country they were not allowed, in America they were. At Montreal, where the tramways absorbed perhaps 8,000 HP, the source of their electricity was about 84 miles away, on the St. Maurice River. The whole of it was conducted that distance through three cables, made *not* in copper, but in *Aluminium.* In England, except in one or two small cases, he did not know of aluminium being used for cables, but in America it was used to a large extent; and when it was borne in mind that aluminium had a conductivity compared with copper of fully $\frac{6}{10}$ths, and was considerably less than $\frac{1}{3}$rd the *weight* of copper, the increased size necessary to get the same conductivity had been found to be no objection to these leads being used. In the Montreal installation the three cables were carried all the 84 miles on poles, and apparently they had worked remarkably well. The cables being arranged in three lines forming an equilateral triangle; one of the cables is carried on the top of the pole, and the other two at the ends of a cross arm, the centre to centre of the three cables being five feet.

Each of the three cables was composed of seven strands of No. 7 aluminium wire—giving a total in the three cables of 21 strands.

The total drop in this transmission line of 84·3 miles, where 8,000 HP are being delivered at Montreal, was at unity power factor, about 18% of the delivered voltage, requiring about 50,000 volts at the generating station.

In England we were adhering to the use of copper principally, and we were perhaps 10 or 15 years after Germany and other countries; but it seemed to him that a considerable reduction in the cost of these installations would arise as soon as we were better able to understand the advantages of the new metal.

He wished to express his thanks to the author for the very wide view he had taken of the subject, and the interesting matter contained in the paper.

Mr. A. Etchells protested against the "blind faith" with which the records of ammeters were taken by some electrical engineers, and thought it was very desirable that these instruments should be correct. An instance occurred on this point in connection with the driving of a centrifugal pump for condensing in combination with an ejector condenser. A small steam engine drove this pump, and broke down. The works were equipped with electric motors, and they used one to drive the centrifugal pump, and the electrician of the works said that the pump was using 27 HP. It was physically impossible for the engine driving the pump to develop 27 HP, as to do so would have required a mean effective pressure of three times the boiler pressure. On indicating the engine subsequently, it was found to be 8·9 HP. The incident nearly led to the discontinuance of the use of the condensing system on the plant.

Mr. J. P. Bedson mentioned in continuation of Mr. Etchells' remarks respecting ammeters varying, that they did vary, but despite that they were a very great advantage where electric power was used. Twelve years ago his firm put down an

electrical installation which included the largest continuous current dynamo which had then been put down in this country; it was a very bold step and was criticised freely. That machinery had been running from then up to the present time practically night and day and it was still running well. As a pioneer plant, of course there had been a lot of troubles. Every machine had a separate motor, and the powers required were from 5 to 20HP, and to each of these machines was a cut-off switch as well as a starting switch, and an ammeter. One of the greatest pleasures in going round the works was to go past the switchboards and see what current each machine was taking. Many times in this way by noting the ammeter readings he had found the machines had been going wrong and that something was getting hot.

An interesting point came within his knowledge a short time ago which showed the advantages of electricity. He had two machines running, each doing exactly the same work, but the gearing was different, and the question required settling as to which of the two machines was the better. One factor only settled it; the ammeter showed that one machine was taking 17 HP, and the other doing identically the same work was taking 22HP.

Respecting the question of Corporation costs and private concerns, of course a Corporation has not to make any mistakes, or at any rate as few as possible, as nobody would bear the load, but in a private concern if any mistakes were made somebody would bear the load and would run a little nearer the wind. At the same time he thought that many of the electrical engineers, or engineers generally, were responsible for the large plants installed, and that they went to very unnecessary expense. Some years ago he was interested in the building of a chimney, and obtained a lot of data on the subject; it took a minimum amount of bricks, and had an extra amount of stability, it was

90 yards high, 10ft. 6in. in the clear at the top, with the brickwork at the ground line two bricks and a half thick. This chimney had been standing 24 years and had done excellent work. He had lately been in a Corporation electric station, and noticed that the base of the chimney above the ground line was 11 bricks thick. That was where the money was wasted, a private firm would not have allowed their engineer or architect to go that expense.

One paragraph in the paper, he thought, spoke volumes for electricity, and that was the reference to horse haulage in collieries where the work they did for ½d. a ton would otherwise have cost 4½d a ton by horse haulage. He understood that this was hauling the coal in the pit and not above.

The author had given a passing word to the late Mr. Willans, to whom obligations were due for his beautiful little engine.

He (Mr. Bedson) was afraid that this had demoralized a good many English electrical engineers, and engineers generally, for they had gone in for high speed plants in this country owing to this engine, where otherwise they would have gone in for slow speed. England was the only country where they had done this; the German engineers had realised more quickly than English the advantages of slow speed. With slow speed plants for driving dynamos the plant was expensive perhaps, but the upkeep was low. He knew a Continental firm 16 years ago who had never then built anything more than a small dynamo, and they undertook to fit a 600HP slow speed generator running at 82 revolutions a minute, and they also agreed to forfeit five francs per minute for every time the generator stopped in the mill. That firm put in a cross compound slow speed engine to drive the generator, and the engine ran for two years night and day, and they had not paid £5 for fines in that time.

In England we were also realising this, but on the Continent there were plants that had been put down 15 or 16 years ago

which were up-to-date even at the present time, and which were running at slow speed with a very good economy in coal.

Mr. R. J. H. Sayers said that he had been very much interested with the paper, as he felt sure that the use of motors for many purposes would be extended; he had for a number of years been engaged on special machinery which had to be driven by steam power transmitted some distance. This was connected with gas-works, and many gas-works' engineers were now considering the advisability of introducing electricity generated by gas engines into their own works for driving machinery. Electrical driving had come very strongly before engineers during the last few years. The transmission of power he had been accustomed to adopt had been compressed air and rope driving both by cotton and wire ropes, and this means had had to be adopted owing to the machinery being some distance away from the generating plant. It was now a very serious question as to whether electricity would not help them over their difficulties, and during the last year his firm had put down about 25 motors in connection with various machines, and they had been well satisfied with the results in many instances, although as far as economy was concerned they had not yet made up their minds.

He also wished to express his appreciation of the value of the ammeter. When designing a piece of machinery it was formerly very difficult to find out the power required by the plant, especially if the plant was not of a common kind. Since using the ammeter, however, on these electric motors he had been able to find out exactly the power required for various classes of work, and it had been very interesting to find by the aid of the ammeter that some part of the plant which it had been believed took a lot of power really took less, and other parts which it had been thought took a little power took more than had been calculated.

Respecting aluminium cables he had recently been asked the advantages of aluminium as against copper cables. Aluminium was a metal which had been very much boasted about, and he personally thought it had been over-estimated, and it had been a great disappointment to many people. He wished to know whether it was as reliable as copper for strength, apart from its cost, and whether Mr. Metzger would recommend aluminium cables in place of copper.

Mr. George Saxon mentioned that apparently from what his brother Mr. Alfred Saxon had already said it would be believed that his firm were hardly favourable to the development of electricity and electric plant, but such was not the case, as would be proved by the fact that their own works were electrically equipped. It was only the fact that some electricians seemed to imagine that electric developments should apply to everything all round, but it was well known, however, that although it was applicable both economically and advantageously to certain developments of mechanical energy, to apply it all round had been proved to be absolutely wrong, and until experience proved it to be right for certain equipments then the present motive power, even mechanical, would hold its place.

Mr. H. N. Bickerton thought that all the members would agree that the paper was very full and complete, but he would like to ask whether the author had any data as to the percentage of loss which occurred in the distribution of electricity through the cables, and also as to the ratio between the cost of the cables and the generating installation, although he knew the latter varied considerably in all districts. It seemed to him that these must be very considerable items, otherwise the electric current would be sold at something less than ½d. per unit. The cost of its generation must be very much less than that figure, as with

the assistance of a gas engine and suction plant there was no difficulty in generating on even a small scale, electricity at a cost of about ·2d. per unit, and on a reasonably sized scale at almost $\frac{1}{10}$th of a penny per unit. Therefore if such results could be got on a small scale locally, he did not see how for a considerable time the central power station would pay with local installations.

Mr. Robert Matthews said that before calling upon the author for his reply, he wished to enter a protest against the municipal charges for electricity; he thought it was a great scandal that a free trade city like Manchester charged what it did for their electricity. Taking the case of his own firm of Armstrong, Whitworth & Co., they were hemmed in on all sides by railway and streets, and would have taken the electric power from the Corporation if they could have got it at a fair price. If that was the case with his firm, how many others were there similarly placed? He hoped that all members would protest against this gross arrangement of municipal trading. Why had the Lancashire Power Company been prevented from supplying them with power from mains, and why had they not the right of taking the power from them? He did not understand it, and thought it a very great injustice, and he hoped that everyone would impress on the municipal people the advisability of opening the market.

Mr. A. Gem said that he deprecated the use of large numbers of overhead cables running about all over the populous parts of the country with something like 11,000 volts running through. The Post Office authorities, owing to damage caused to the overhead wires, etc., had found the disorganisation to the telegraph system was so great that they had now resorted to underground wires. He thought the same thing would apply to

the cables for the carrying of electricity, apart from the danger to persons passing underneath.

Mr. G. F. METZGER, in replying to the discussion, remarked that the question of municipal trading seemed to have taken the speakers' fancies, but he was afraid he could not go into any further details on that subject, and being a late Manchester Corporation official he preferred not to make any further remarks than those given in the paper. Mr. Parry, however, had referred to the town of Heywood, where (he stated) a bad and expensive Corporation supply existed, and that he was paying 6d. per unit. That, Mr. Metzger said, simply bore out the remarks in his paper, viz., that small Corporations should not be entrusted with the electric lighting of the town; not even a private enterprise would dare to tackle some of these small towns, but which had been equipped municipally with electric light.

Mr. Saxon had raised many points which, however, had been replied to partly by other speakers in the discussion, who disagreed with Mr. Saxon's remarks. He also could not concur with Mr. Saxon's criticisms. He had no doubt there were mills in the country where there was as much as 40% loss from friction, but there were others with less.

Mr. A. SAXON asked if Mr. Metzger was referring to new cotton mills.

Mr. METZGER replied that he referred to cotton mills erected within the last ten years. Continuing, he said that if Mr. Saxon and other members had had the advantage of seeing some electrically driven mills abroad, Lancashire not being the only place where mills existed, he would have changed his opinion very considerably on electric driving, and would not consider the matter a "fairy tale." Mr. Metzger had been through a

mill where the working costs had to be kept down to a minimum owing to the severe competition. They put up this mill first steam driven throughout, and then changed to electric driving, resulting in the working expenses being reduced to such an extent that other mills had to follow suit and put in electric driving. He thought that was sufficient testimony for electric driving, but everything depended upon efficient and careful installation of the correct type of plant.

Mr. Saxon had referred especially to a mill at Pendlebury.

Mr. Metzger had heard that a mill was to be equipped electrically at Pendlebury, but that was not the mill he referred to in the paper; he was referring unfortunately to the foreign mills electrically driven; as Mr. Cook had said, the officials did not know or would not say what the results were.

In the paper he had made a specific point that in his opinion the specifications for the electrical portion of electrically equipped mills should be got out by qualified electrical engineers. Mr. Saxon had quoted from a specification of an electrically equipped mill, and said that there were an immense number of yards of shafting and belting. He would like Mr. Saxon to say whether that specification had been got out by a qualified electrical engineer.

Mr. A. Saxon remarked that he expected it had been got out in conjunction with an electrical engineer, although it was not signed by one, but by an architect.

Mr. Metzger continuing, said that answer bore out his point exactly; he did not think that architects were ever intended to get out electrical specifications any more than engineers were intended to get out architects' specifications. It was surprising to see the number of specifications now sent out, to which contractors were asked to tender for engines, dynamos, boilers,

etc., and which had not been signed by competent mechanical or electrical engineers. He was not surprised about the thousand yards of shafting specified, and would not have been surprised if it had been two thousand under the circumstances.

Respecting Mr. Walthew's reference to accumulator cars and a combined system of overhead wires and accumulators, Mr. Metzger stated he had seen a similar system in Berlin and Brussels. The reason it was done in Berlin was not because it would effect the view of the sky-line, but because the municipal authorities would not allow any overhead wires in that district. That system was gradually being done away with for the surface contact system on account of the large prime cost, and especially the very heavy maintenance expenses.

The slot rail which had been referred to as being used in Brussels was simply a deviation of the ordinary system; instead of putting the slot in the middle they put it at the side. The disadvantage of that was that they got two slots side by side, one in the tramway rail itself, the second being the slot for the insertion of the plough.

Mr. Walthew had made reference to the Ilgner system for colliery work, and had asked whether Mr. Metzger could recommend that system everywhere. The author replied that the system in question was intended to deal first of all with several pits, one generating station being used for serving them with power, as for instance at Grand Hornu, Belgium, it paid extremely well.

In several collieries he had seen abroad, he had noticed the care the colliery owners took, especially in the engine rooms, not only with the engines themselves and the buildings—which would put some of the English electricity stations to shame—but in the complete arrangements for making every saving in steam and coal whenever they got an opportunity. Very few

collieries allowed their waste steam to exhaust into the atmosphere, they put in the very best type of mechanical stokers to save the coal; at one time the coal dust was given away, but now they use it, with the result that they can declare abnormal dividends; in one colliery the chairman had to apologise to his shareholders for the dividend being less than the previous year, as they could only pay 120% as against a previous 135%. That fact showed what they could do in Germany with economical working.

Mr. Cook had stated that in estimates he had received for installing electrical power in a mill, that the cost of the motors—which he presumed included the dynamos—over and above an ordinary steam driven mill was £5,000. He (Mr. Metzger) was surprised that it was not more, as this sum of £5,000 at 5% interest was only £250 per annum. If an electrically driven mill could not save considerably more than £250 per year over a steam plant, it would not be worth installing. It was not necessary to pick out any one particular advantage of electric driving which electricity presented over steam, and provided everything was properly designed, the right size of motors used, and the "yards and yards of shafting and belting" mentioned by Mr. Saxon not employed, the results could but effect better and more steady running with reduced costs all round.

The question of tramways versus motor buses in outlying districts was rather an interesting point at the present time, but he was not prepared to go into figures; his belief, however, was that the motor-buses would not in their present design be on the road very long, the cost of their maintenance, as proved in London, being exceedingly heavy. The buses now to be seen in London and which ran so beautifully and silently when first installed, were now rather noisy and required no horn to announce their approach.

There was another system in which electric buses were supplied with current from an overhead wire. This vehicle did not run on rails, but could be manipulated over the whole width of the road.

An unfortunate ammeter had been critised, an electrician having reported that a motor was showing 27 HP output, but in reality it was only 8·9. He hoped that the gentleman who reported that was not an electrician, as to him (Mr. Metzger) it appeared that the engineer had got hold of an instrument not intended for either the current or the pressure for which it had been used, unless it was a cheap and unreliable instrument.

Mr. Bedson had referred to the Willans' high speed engine, and had made comparisons between what had been done in England and Germany in this particular branch of engineering. There was an explanation of why high speed engines were adopted here, as against low-speed abroad. English manufacturers had until comparatively recent date, not mastered the manufacture of slow speed dynamos. If slow speed engines had been adopted, belt or rope driving would have to be resorted to. One of the first companies in England using this combination was at Newcastle, where several slow speed compound Robey engines drove high speed alternators, and this was done because it was impossible at that time to design an alternator for the slow speed if driven direct. In Germany they had conquered the difficulties earlier than we had, and in the Frankfort Exhibition of 1892, he saw a high speed alternator running coupled direct to a slow speed engine, although it was not until eight years after that English manufacturers could make a similar machine.

The question of overhead cables had been referred to by several speakers. He did not want them to get the idea that there were no overhead cables in this country, as he had stated that they were gradually being allowed. As a matter of fact

the Manchester Corporation had received permission to run overhead cables for supplying current to some of the proposed outlying tramway routes, these cables being supported by brackets on the posts carrying the overhead wires. It was, however, not intended that overhead wires should be permitted through the town, but only that they should be used in country places, and as they do abroad. There was absolutely no more danger attached to these wires in England than in Germany. Many an electricity undertaking would be saved if they had been allowed in place of the costly underground network of cables.

Aluminium wires in this country were not practicable at present, and the English atmosphere seemed to deteriorate the metal and make it brittle. Some experiments had recently been carried out with aluminium cables, the cables being left up for twelve months in a mining country, where there was a quantity of sulphur in the atmosphere, and after twelve months they were so brittle that they had to be removed. He thought that the Manchester atmosphere would affect them still more. His belief was that aluminium would sooner or later replace underground copper cables at a reduced cost.

A very large question had been asked him, which time would not permit him to go into, regarding the percentage of loss which occurred through the generators and distribution generally in an electric lighting system. That loss would naturally depend on the system which had been adopted, but it might be taken that with low tension the losses were less, and with high tension with motor generators the losses were heavy, running up to about 30%, and with accumulators they were still more. No doubt the most efficient was the moderate pressure, say 400 to 500 volts, low tension distribution, in which case the losses could be reduced to about 6%.

THE TEXTILE INDUSTRY.

READ SATURDAY, 24TH FEBRUARY, 1906,

BY

Mr. W. H. COOK & Mr. JOSEPH H. STUBBS,

(MANCHESTER.)

In all probability the majority of the audience to-night are Lancashire men and as a consequence, cannot help but be acquainted with the fact that the main and most important industry in the district is the textile industry. It has more money invested in buildings and plant, and employs more work-people, directly and indirectly, than any other branch of trade in the country. Thus you will readily understand that to give a resumé of its operations during the past fifty years, is a task from which the writers shrink. However, it is hoped to bring before you information which will be both interesting and instructive.

The progress and development of the textile industry has brought in its train other trades, which, altogether, have made Lancashire the busiest and most go-a-head county in the British Isles. We all know that London has the greatest population of any city in this country, yet, when we take a radius of 30 miles, the centre being the Manchester Royal Exchange, we have a greater number of inhabitants than there is within the same radius of the Metropolis. This is, in the writers opinion, owing to the existence of the textile industry. It is not intended to give, in detail, all the branches of the textiles, such as woollen, linen, silk, etc., but to consider the more important one, that is, cotton.

It is supposed that the manufacture of cotton originated in India about 1100 B.C., and the methods then used have practically remained the same, until within a comparatively recent date. The Hindoos spun yarn and manufactured material of as fine a quality as can be produced to-day in any Lancashire mill, equipped with the best and most modern machinery. In the course of ordinary events, the trade in cotton and cotton goods spread westwards, until we find it in Italy in the 14th, Germany, Prussia and England in the 16th, France the 17th and in Russia in the 18th century.

The first reported importation of cotton into England was in the year 1298, and it was mainly used for candlewick. Manchester goods, which were principally made from a mixture of woollen and cotton, or linen and cotton, were first heard of in the year 1352.

In writing this paper the original intention was mainly to give a record of the mechanical inventions in connection with textile machinery during the last 50 years.

In commencing to prepare the matter, the writers were astonished at the small number of such inventions of any great moment, and it was a little disappointing to find that most of the radical ideas of the various machines were brought out long before this Association was formed.

Wyatt invented the drawing-frame and Kay the fly-shuttle in 1738. Lewis Paul the card in 1748, and the clever doffing comb mechanism about 1750.

Hargreaves invented the spinning-jinney in 1764 and Crompton the mule in 1779.

The scutcher was invented in 1797 to be improved by the addition of the lap-end by Mr. Creighton 50 years later, and the piano-feed regulator by Mr. Lord in 1862.

Holdsworth brought out his wonderful differential motion in 1830.

It is so far back as 1825 that Richard Roberts invented his self-acting mule, and even the ring-frame, which has made such tremendous strides during the last 30 years, was invented more than 80 years ago.

After reading such a list and bearing in mind that most of these inventors had no mechanical training, one is apt to feel very small and to raise the hat to those whom we, at the present time, are accustomed to consider were so far behind us in knowledge and ability.

Many inventions have been brought out during the last 50 years, but the majority have been in connection with the detail parts, and although such inventions have improved the machines and rendered them more perfect, very few of them have embodied any great new principle.

The writers have therefore decided to make the paper a record of:—

1. *The Inventions which have had the greatest effect on the Textile Industry.*
2. *(a) The Changes in Methods.*
   (b) Reduction of Costs of Machinery.
   (c) Production and Costs of Yarn and Cloth.
3. *The Changes in the Social and Economic Conditions of the Cotton Mill Operatives.*

I. THE INVENTIONS WHICH HAVE HAD THE GREATEST EFFECT ON THE TEXTILE INDUSTRY.

The first and outstanding patent is the "Heileman" comber. The introduction of this machine into this country took place in 1856, the same year that this Association was inaugurated. It has brought about quite a revolution in the production of fine yarns, as it has enabled the spinner to produce yarns as high as 400^s counts; that is to say, of so fine a structure that over a third of a million yards, or 191 miles, are required to weigh 1lb., and yet not vary more than 5% in regularity. This is undoubtedly

a marvellous achievement, when the delicacy of the cotton fibre is considered. Sample No. 1, Cop of Yarn No. 400^s.

A description of the clever motions embodied in the machine would form a paper itself, but seeing most of our members are not engaged in the textile industry, the writers do not think it wise to trouble them with too much detail.

Briefly its action may be described as follows:—

The cotton fibres are placed behind the machine in the form of a lap, being mixed together in all lengths, which would, if allowed to go forward in this condition, make weak and uneven yarn.

As they are passed through the various parts of the machine, the short fibres are taken out with almost human accuracy, and none but those of a certain length allowed to go forward, the resultant product being a most regular sliver with the fibres lying parallel to each other, and in the best positions for strength and regularity. During the last year or two this machine has received special attention, with the result that further improvements have been made. Samples No. 2 a lap, No. 3 a sliver and No. 4 waste, are on the table for inspection. Fig. 1, Plate I., Comber, 1856. Fig. 2, Plate I., Comber, 1905.

After the comber comes the revolving flat card, in which the old rollers and clearers of the roller and clearer card with the inconvenience and dirt, are replaced by a travelling apron of flats or combs. This machine has taken many years to secure universal adoption, but on account of the cleaner work produced and the less cost for attention, it is now used in almost every case, except for very low counts and waste, but it must be said that there are still many people who contend that the greater amount of waste made, more than counteracts the saving in labour.

The percentage of waste in the roller and clearer card is generally about 2, whereas in the revolving flat card it is 5.

Fig. 3, Plate II., Roller and Clearer card, 1856 and Fig. 4, Plate II., Revolving Flat Card, 1905.

Another great improvement is the presser used in connection with preparation frame spindles. This is a very simple but most effective addition to the spindle, and as will be seen from the samples on the table, consists of the addition to the old flyer of a loose leg, to which is added a foot called the "presser." The outer part, or leg, is heavier than the inner part, or foot, and during revolution the centrifugal force of the leg being greater than that of the foot, causes an inward pressure on the bobbin, thus enabling the machine to make a bobbin which is not so liable to damage in the after process, and also contains a much greater length of material. This improvement has tended, in a great degree, to the reduction of cost in the preparatory stages of spinning. The samples Nos. 5 and 6 spindles and bobbins on the table will plainly show this improvement.

The piano-feed motion on scutcher. The piano-feed regulator patented in 1862 by Mr. Lord, is also worthy of notice. This invention has for its object the regulating of the lap. It consists of a number of pedals like the keys on a piano. These pedals "feel" the cotton and if it is too thick or too thin, they put into action a motion which decreases or increases the rate of feed, thus automatically adjusting the volume of cotton in accordance with the weight per yard decided upon. It is a very simple arrangement, but one which appeals to an engineer on account of its simplicity and accuracy in working. Fig. 5, Plate III., Scutcher with Piano-feed.

Another patent of importance is the "Rabbeth" spindle for ring spinning and doubling frames. When the ring frame was first introduced it had top and bottom bearings for the spindle which required oiling every day. This, besides being troublesome, was liable to cause dirty yarn, and it was not possible to

run the spindle at a greater speed than 5,000 revs. per minute, whereas the "Rabbeth," or self-contained gravity spindle, sample No. 7, shown in section on the table, and in Fig. 6, Plate IV., only requires oiling about every two months, and even with an un-balanced bobbin will run steadily at 20,000 revs. per minute, a speed much higher than is required, the maximum speed at which the worker can attend to the frame being about 10,000 revs. It will readily be seen what a great effect this patent has had in increasing the production of yarn. Fig. 7, Plate IV., Ring Spinning Frame, 1856. Fig. 8, Plate IV., Ring Spinning Frame, 1905.

Another patent is the Cross Winding Frame, shown in Fig. 9, Plate V. This machine was rendered necessary mainly on account of the changes in the location of the spinning and the weaving mills and to meet the different conditions existing between mule and ring spinning mills, as also the hostile foreign tariffs. These varied conditions made it necessary to be able to send the yarn from place to place with the smallest possible amount of tares.

On comparing the sample bobbin No. 8 made on the bobbin winding frame with the cheese or spool, sample No. 9, made on the cross winding frame, it will be seen how this has been accomplished.

Illustrated in Fig. 11, Plate VI., is another type of winding frame, to wind the yarn from mule cops or ring spinning bobbins on to bobbins for the purpose of warping. The yarn in its course from bobbin to bobbin generally passes through adjustable yarn clearers in order to take away faulty places or knots. Fig. 10, Plate VI., Winding Frame as made in 1856.

Then of late years we have had the introduction of the automatic feeder into the blowing room. This machine automatically regulates the supply of cotton to the cylinder or beater

of the opener, and thus more regular laps of cotton are produced than formerly, besides reducing the cost of attention 50%.

The change will be easily seen on comparing Fig. 12, Plate VII., Blowing-room, 1856, with Fig. 13, Plate VII., Blowing-room, 1905.

The reeling of yarn into hanks has assumed a greater importance during recent years. The exact measuring of the number of yards per hank has been more rigidly insisted upon and therefore the machine, as a consequence, has had to be made more exact in its operations. Formerly, the measuring was done mainly by the operative, and now this is done automatically by the machine. Fig. 14, Plate VIII., Reel, 1856. Fig. 15, Plate VIII., Reel, 1905.

The gassing of yarns, in order to remove the loose fibres has also become a more important process, and therefore more attention has been given to improving the machine. The general practice now in use is to gas the yarn on to cheeses or spools, thus avoiding the use of wooden bobbins. The yarn in this form is more convenient and speedily transferred into hanks, as the swift of the reel can be revolved at a much greater speed, with less breakages of the yarn. Fig. 16, Plate IX., Gassing Frame, 1856. Fig. 17, Plate IX., Gassing Frame, 1905.

For certain classes and qualities, the yarn spun on the mule is still considered to be superior to that produced on the ring spinning frame, especially for the very fine counts. Although the self-acting mule was invented and introduced some considerable time previous to 1856, the main principles are still the same, and the same facts hold good that this machine has only been improved in its detail parts. One of the main improvements is concerning the number of spindles per mule. In 1856 and 1905 they were 500 and 1,300 respectively. The illustration Fig. 18, Plate X. is interesting, as it shows a female piecer,

which class of operative was very common in 1856, but now very rarely seen. Fig. 18, Plate X., Mule, 1856. Fig. 19, Plate X., Mule, 1905.

Finally, in our choice of inventions the writers desire to mention the introduction of the various new types of looms. Previous to these there had been no radical alteration in the design of the loom for more than 50 years. The automatic loom has made rather slow progress in England up to the present time, but there is no doubt they have come to stay. When it is borne in mind that a weaver can only attend to six looms of the old type, as a maximum, whereas he can attend to twenty-four or more of the new type, it will be seen that these automatic looms have a future before them. Fig. 20, Plate XI., Loom, 1856. Fig. 21, Plate XI., Automatic Loom, 1905.

It may be said that there are other inventions of equal importance, but the writers think the above mentioned inventions and improvements are principally those which have had the greatest effect on the textile industry during the last 50 years.

2. (a) THE CHANGES IN METHODS. (b) REDUCTION OF COSTS OF MACHINERY. (c) PRODUCTION AND COSTS OF YARN AND CLOTH.

(*a*) *The changes in Methods.*—In 1856 the average spinning mill was constructed after the design shown in Fig. 22, Plate XII., and contained about 30,000 spindles, producing yarn of 32^s average counts. This illustration was recently obtained, hence the electric trolley wires.

The mill rooms, generally, were narrow, low, short of light, ill-ventilated and with exceedingly poor and indifferent sanitary arrangements.

The power was in some cases transmitted by means of a water wheel, but steam engines were more generally adopted, even at this period.

The boilers were principally of the Cornish, or single-flued type, made of iron, in sizes up to 25ft. long × 6ft. diameter and worked at a steam pressure of 20 to 60lbs. per square inch. The Lancashire or two-flued type of boiler was just being introduced at this time.

The engines were of the beam type single condensing with cylinders up to 60in. diameter and 8ft. stroke, and ran at about 20 to 30 revolutions per minute. The steam consumption was about 25lbs. per IHP and the coal consumption about 3½ to 5lbs. per IHP. Such beam engines were made to transmit powers up to 200 IHP.

Spur gearing was generally used to transmit the power from the crank-shaft to the second motion-shaft, from which it was transmitted to the main shafts in the various rooms, by means of vertical shafts and spur bevel-wheels.

The mill hours were 60 per week. The spinning spindles were either of the mule or flyer type, revolving at the rate of 6,000 and 3,500 revolutions per minute respectively and produced ·52lbs. and ·4lbs. of yarn, average counts 32^s per spindle per week respectively.

The cost of a spinning mill was from 45/- to 50/- per spindle.

The cost of a weaving shed was £15 per loom, including buildings, boilers, engines, gearing and accessories, in both cases.

At the present time, the average mill contains about 80,000 spindles and the yarn produced may be taken at an average of 40^s counts. The buildings are of the most approved design, for the health of the operative, cheap production and economical driving. (See Fig. 23, Plate XII.) The arrangement of the mill and machinery is such that the raw cotton from the bale passes through the various processes and arrives as yarn or cloth at the warehouse, without traversing the same path more

than once, that is, it pursues the shortest course possible in order to save waste of money in handling.

The power is transmitted by a variety of prime movers, but the majority of mills are driven by steam engines.

Steam is generated in steel boilers of the Lancashire type as large as 30ft. long by 8ft. 6in. diameter at a pressure as high as 200lbs. per square inch. Economisers, feed water heaters, are invariably installed to obtain the greatest possible efficiency from the heat value of the coal, &c., and in some cases steam superheaters have been installed.

The engines are reciprocating, and both vertical and horizontal, of double, triple, and in some cases quadruple expansion, are the types adopted, and to-day engines are working in cotton mills up to 2,500 IHP. The cylinders are made up to 65in. diameter, with stroke up to 6ft. The crank shafts make 60 to 80 revolutions, and are fitted with fly-wheels in the form of rope pulleys up to 30ft. diameter, prepared to receive as many as fifty ropes of 1⅝in. diameter, for driving the main shafts in the various rooms. The steam consumption of such engines is from 12 to 16lbs. and the coal consumption about 1½ to 2lb. per IHP. In cases where superheated steam is used the compound engines are about as economical as the triple-expansion working under ordinary conditions.

Turbines have also been installed in several instances with (it is said) satisfactory results, and it seems as though they will become strong competitors of the reciprocating engines in the near future. At one mill in this district a 750 kilowatt turbo-generator has just been installed. The writers have not been able to secure any reliable data as to the economy of this type of prime mover, but understand that the usual design consumes about 14lb. of steam per IHP for powers up to 650. It is to be regretted that no English makers feel inclined to give exact data, perhaps they do not think it advisable.

Driving by means of gas engines is also being introduced, but not yet to any great extent.

Electricity has been adopted both at home and abroad in some instances, but it has not yet made much progress in England.

There are, however, several mills being erected which will be equipped with electric driving, but so far no particulars can be obtained as to what it will cost to equip and drive, in comparison with steam plants of the regular type.

The following data has been obtained in connection with a small plant erected in this district in 1902.

The electricity is generated by means of a 60 kilowatt alternating current three-phase dynamo, 60 period, 440 volts, belt-driven from the existing mill engine. The current is used for driving eight ring spinning frames, each frame being driven by a separate motor of 7½HP. The motor is connected to the driving shaft of the frame by a flexible coupling. The yarn spun is the usual Bolton fine counts. The increase in the production is estimated at from 3 to 7%, mainly owing to the more constant speed and therefore fewer broken ends. The cost of the current as compared with the usual drive, cannot be obtained, nor the cost of the upkeep. The particulars are certainly meagre, but they are the best to be obtained.

Another installation has recently been put into operation, but with what results the writers cannot say, except that they understand that the current is being supplied by a power company at a price not to exceed the cost of steam driving.

The writers had intended to give some details of some mills, electrically equipped, in Italy, where they are certainly ahead of us in this class of drive, but up to the time of going to press the data had not arrived.* They hope to receive it in time to be published in the next Transactions of this Association. The writers are very disappointed and exceedingly sorry this information is not to hand.

* Since writing the above these particulars have come to hand. See Appendix No. 2.

The present mill hours are 55½ per week. The flyer frame has become almost obsolete, and the mills are now either equipped with mules or ring frames, and in some cases with both types of spinning machinery. Mule spindles and ring spindles revolve at 11,000 and 9,500 revolutions per minute respectively, and produce ·75 and 1lb. of yarn, average counts 40^s, per spindle per week respectively.

The various processes through which the cotton passes, from its arrival at the mill in the bale to its leaving the mill as yarn or cloth, are shown in diagramatic form in Fig. 24, Plate XIII.

The cost of a mule spinning mill is from 19/- to 21/6 per spindle; the cost of a ring spinning mill is from 36/- to 42/- per spindle; the cost of a weaving shed is £26 per loom; including buildings, boilers, engines, gearing, and accessories in each case.

It ought to be stated that most of the extra cost of the ring mill arises from the greater production per spinning spindle, which, as a consequence, requires more preparation machinery, also, that a modern weaving shed is fitted up in a far superior manner to that in 1856, in every way, especially the warehouse accommodation.

(*b*) ***Reduction of Costs of Machinery.***—The foregoing figures very forcibly show the progress made in the reduction of the cost of spinning machinery for the complete equipment of a cotton mill. If a comparison is made for the two periods of the hours worked and wages paid to the skilled artisan in the engineering and machine making trades, the progress is still more noticeable.

Table I. (Page 121 gives particulars of hours worked and wages paid in the two periods. From this it will be seen, taking into account the fewer working hours and the higher rate of wages, the average increase is equal to 24%.

TABLE I.—Hours Worked and Average Wages Paid to Skilled Artisans in Manchester District.

	1856.—57½ Hours Per Week.				1905.—53 Hours Per Week.			
Trade.	Engineering.		Machine Making.		Engineering.		Machine Making.	
	s.	d.	s.	d.	s.	d.	s.	d.
Pattern Makers ..	32	0	30	0	40	0	40	0
Moulders	34	0	34	0	40	0	40	0
Smiths	32	0	28	0	36	0	34	0
Fitters	32	0	28	0	36	0	34	0
Turners	32	0	28	0	36	0	34	0
Grinders	..		30	0	..		36	0
Joiners	..		28	0	..		34	0
Average	32	4·8	29	5·1	37	7·2	36	0

It was in order to reduce the cost of production of textile machinery that most of the improvements in machine tools have been made, and many most ingenious machines have been introduced into the workshops. The following are a few instances:—

The automatic stud and screw lathes, which make studs and screws from the solid bar, thus practically dispensing with the process of forging. The circular and other types of milling machines, the quick return planer, and others, in fact these high speed automatic and semi-automatic machines are being introduced to such an extent that the proportion of skilled to unskilled artisans, or rather those who have served an apprenticeship and those who have not, is quickly changing until it seems as though at no distant date, turners and fitters will be a very small proportion of the men employed in the textile machinery industry in comparison to the number employed in 1856.

When this Association was formed a workman who could cut a screw or wheel was considered very clever indeed; to-day

these operations are reduced to the simplest form; screws can now be cut in the screw miller sufficiently exact at a very low cost by a labourer, and gear wheels are cut so cheaply that it is the common practice to have all cut wheels in cotton machines, the price paid, piece-work, being about 1s. 3d. per 1,000 teeth for wheels up to ⅜in. pitch.

The writers have brought a few samples, which lie on the table to show various detail parts made on automatic machines, and will be pleased to give any information relating to wage cost of same.

Sample
No. 10.—Sleeve.
„ 11.—Inner Tube.
„ 12.—Bolster.
„ 13.—Wheel Blank.

Sample
No. 14.—Rope Pulley (milled).
„ 15.—Brass Bowl.
„ 16.—Stud.

The reduction is further clearly seen when we compare the 1856 and 1905 selling prices of the finished machines as shown in Table II.

TABLE II.—Selling Prices of Cotton Mill Machinery.

	1856.	1905.
Scutcher	£80 0 0	£90 0 0 Includes Piano-feed Regulator and Knock-off Motions.
Card	£112 0 0 Double Card.	£65 0 0 Revolving Flats.
Drawing Frames, per Delivery	£9 0 0	£6 10 0
Slubbing Frames, per Spindle	£1 18 0	£1 4 0
Mules, per Spindle.....	6 0	3 6
Ring Frames, per Spindle	9 0	6 0
Upright Spindle Winder, per Spindle	5 0	4 6
Loom (Burnley)	£5 0 0	£6 0 0

Prices of other machines practically show the same reduction. The difference, however, is much greater than even these selling prices show, as the machines to-day have embodied in them so many additions that these make very large increases in the cost.

The writers wish to point out here that there is no doubt the call for cheaper production on the part of the textile machine makers has reacted to the advantage of other trades, particularly the machine tool trade, and undoubtedly thus brought them to a higher state of perfection.

Another point worthy of mention is the fact that although textile machinery has to be of the most accurate finish, the prices for the finished machine do not, in the average, work out at more than £25 per ton, which is an exceedingly low figure, taking into account the large number of parts comprised in a machine.

One of the reasons for this low cost is the special attention that is given to every little detail to reduce its cost to the very lowest in each process of its manufacture. Wherever possible, forgings are replaced by castings. Castings are designed to be easily moulded—that is, with few cores, and the necessary bolt holes and facings so arranged to make moulding a simple job. Laborious hand fitting is replaced by special machine tools and jigs, and the fact that many parts are repeated on the same machine, accounts for automatic and semi-automatic tools being so widely adopted. The polished and bright parts, which are only required for appearances, are obtained in a cheap and satisfactory manner by the processes of grinding and glazing. The large amount of repetition work also conduces to the low cost of production.

(*c*) ***Production and costs of Yarn and Cloth.***—It is well known that the climate of this country is not a suitable one for cotton growing, and that the whole amount of cotton used has to be imported.

Our supplies chiefly come from the United States, South America, India and Egypt, but it is to be hoped that through the praiseworthy efforts of the British Cotton Growing Association, formed in 1901, that in the future a considerable supply will be from our Colonies in West Africa, under our own control, and so to a great extent avoid the fluctuations of arrivals and prices caused many times in late years through the tactics of wild speculators.

Cotton from each country and district has its own characteristics, such as length of staple, strength, and colour, and advantage is taken of each variety to meet the requirements of strength, counts, twist or weft, of the yarns to be produced, and in many instances mills are equipped with machinery specially to work only certain varieties of cotton. It is not thought necessary to enter any further into this part of the subject in this paper, except by Table III. (below) to show the amount of cotton imports from the various sources into the United Kingdom.

TABLE III.—Imports of Raw Cotton.
(Millions of Lbs.).

From	1856.	1880.	1905.
United States America..	780·0	1,226·9	1,729·3
South America	21·8	24·1	31·9
Egypt	34·4	150·5	361·1
India	180·5	207·0	49·2
Other sources.....	7·1	20·7	32·0
Total	1,023·8	1,629·2	2,203·5

Another feature, connected with this part of the subject, ought to be mentioned; that is, the advantages obtained by the use of

TABLE IV.—Production and Costs of Cotton Yarns and Cloths in the United Kingdom.

	1856.	1880.	1905.
Raw Cotton Imports Millions of lbs.....	1,023·8	1,629·2	2,203·5
Raw Cotton Exports Millions of lbs.... ...	146·6	224·6	283·1
*Yarn Production, Millions of lbs., average counts.	745·6	1,194·0	1,632·3
Yarn Exported, Millions of lbs.	182·0	215·7	205·0
Yarn for Home Consumption, Mills. of lbs. av. c.	563·6	978·3	1,427·3
Cloth Production, Millions of yards, average width	3,600·0	7,737·0	11,550·0
Cloth Exported Millions of yards.....	2,036·5	4,496·3	6,198·2
Number of Spindles ..	28,000,000	42,000,000	50,000,000
Number of Looms	300,000	550,000	700,000
Number of Operatives in Spinning Mills	205,000	240,000	211,000†
Number of Operatives in Weaving Mills	175,000	246,000	306,000†
Working Hours per Week	60	56½	55½
Average Weekly Wages 17 classes of Operatives	14s. 6d.	19s. 10d.	26s. 2d.
Operatives per 1,000 Spindles	7·3	5·7	4·2
Production of Yarn per Operative per Year, lbs	3,637·0	4,975·0	7,736·0
Production of Cloth per Operative per Year, yds.	20,580	31,860	37,740
Production of Yarn per Spindle per Year, lbs., average counts	27·0	28·5	32·6
Production of Cloth per Loom per Year, yards, average width	12,000	14,250	16,500
Labour Cost per lb. of Yarn, average counts..	2·4d.	2·0d.	1·06d.
Labour Cost per yard of Cloth, average width ..	·55d.	·447d.	·416d.

* Taking an average of 15% waste. Stocks not taken into account.

† From latest published Blue Books, 1908.

the Manchester Ship Canal. Raw cotton may now be brought to, and yarn and goods shipped from, practically the centre of the cotton industry, thus saving cost of long distance railway carriage.

It is said that one-sixth of the total imports of raw cotton into this country now come by the canal.

From the figures given in Table IV. (Page 125), great progress will be seen to have been made in the amount of yarn and cloth produced, as also in the reduction of the labour costs of the same since 1856.

3. THE CHANGES IN THE SOCIAL AND ECONOMIC CONDITIONS OF COTTON MILL OPERATIVES.

It would be well to notice what effects all these improvements and cheapening of the cost of machinery, as given in the first and second parts of this paper, have had on the social and economic conditions of the operatives. As previously stated, in 1856, machines of the same principles were in use as are to-day, but the operatives did not welcome them by any means. The self-acting mule, perhaps the last machine to supersede the so-called hand machine, was becoming generally adopted for all counts of yarn, but only after fierce opposition on the part of hand mule workers. A paper, "The Union Pilot," printed in the early days of Trades Unionism, said, "Unless a great and speedy change be made in the laws which regulate machinery, we would advise the people to declare war against it—yes, war to the knife."

Their objection was the usual one against all new or improved machinery—that it would displace labour, and the competition of the labour displaced would cause a reduction in wages.

A glance at Table IV., Page 125, will show how wrong such ideas are. In fact, in the textile industry, as in many

other industries, improved machinery has proved to be to the advantage of the operatives, as well as to the employers. This is not always apparent at the time the change is made, but when the operatives have become accustomed to the new conditions, it is seen to be a fact, and the cotton industry is a case in point. Statistics are always open to question, owing to the difficulty of compiling them, caused by the various number of sources and different people from whom they must be obtained.

The figures given in Tables IV., V. and VI., Pages 125, 130 and 131 respectively, are in no ways exaggerated, and may be relied upon, as showing the comparative conditions of cotton mill operatives in 1856 and at the present day. It will be noticed that the social and economic conditions have undoubtedly improved. The writers hope to show that these have been brought about in no small measure by improved, higher-speed machinery, produced at cheaper rates by specialisation and attention to details. Since 1856 the number of operatives has increased 37·6%. Wages have increased 94%. Hours of labour decreased 7·5%. Production per operative increased 112% in spinning mills and 83% in weaving mills, and the cost of production per lb. of yarn and per yard of cloth has decreased 56% and 24% respectively. Some of the improved conditions, have, without doubt, been brought about by the better education of the people, and more stringent and enforced working of the factory laws (which have been altered in many ways favourable to the operative, etc.). It is impossible to conceive, however, how the operatives, working under the system of hand and slow-speed machines, could have had the hours of labour reduced, wages increased, and at the same time increase the amount produced, and thus lower the cost of production.

The old hand machines required a great amount of strenuous manual labour, as well as technical skill. In the present day,

the laborious part of the work is done by the machine and the technical skill required by the operator is the "understanding" of it. His energies are therefore not so fully engaged in the new machinery, which permits him to attend to more, larger, or increased speed machines, hence greater production at less wage cost.

Now, greater production has always been a "bogey" to all operatives engaged in the cotton and other industries. At the time when power machines were superseding hand machines, the operatives objected to increased production, on the grounds that it would reduce wages, and to prevent this, they advocated a reduction in the hours of labour. It was said:—"Let the operatives cease to produce so much, that the demand for their labour may increase."

It did not appear to have entered into their calculations that a necessity produced at a cheaper rate brought that product within the reach of a larger number of buyers and therefore increased the demand.

In the opinion of the writers the operatives had no need to fear greater producing machinery, and if figures prove anything they ought to have welcomed it.

Referring again to Table IV., Page 125, you will see that ever since the cost of production was reduced the demand for cotton yarns and goods has increased in this country. The figures may not appear so favourable to the above statement as they really are, but this is on account of the goods now produced being of a finer quality than formerly.

This increased demand has also taken place in the face of keener competition of other countries. That foreign competition must be keener is to be proved by the amount of textile machinery exported.

In 1856, we exported machinery of all kinds (except steam engines), value £1,921,032.

In 1880, machinery of all kinds (except steam engines), value £6,471,281, and in 1905, the amount of textile machinery *alone* was of the value of £5,607,436.

Number of Operatives and Half-Timers.—In 1856 there were 380,000 operatives employed in the cotton industry of the United Kingdom, and of these 15,000 were half-timers. Half-timers were allowed to commence work at nine years of age. It is said that nineteen out of twenty cotton operatives commenced work at this early age, and, as a consequence, their education was seriously neglected. They were allowed to become full-timers at the age of thirteen years. According to the latest Blue Book published in 1903, there are about 523,000 operatives employed in cotton mills, and of these 21,000 are half-timers, who, however, are not allowed to commence work until twelve years of age, and even then they must have made 300 attendances at school for each five preceding years. The full-time age is now thirteen years, and the school attendance must have been 350 per year, or fourteen years if without certificate of proficiency.

Hours and Wages.—In 1856 the operatives worked 60 hours, and to-day 55½ hours per week.

In 1856 the average wages of seventeen classes of cotton operatives, including overlookers were 14s. 6d. per week, and to-day the same classes average 26s. 2d. per week, as shown by Table V. (Page 130), but taking the reduction of hours into account, the average is 28s. 3½d. per week.

The question will now arise, "Are the operatives, or the industry in any better position on account of the higher wages?" Mr. Schoenhof, in his book, "Economy of High Wages," says:—"A high rate of wages expresses a high consuming power. A relatively high consuming power and a high standard of living are required to make the labourer efficient in body and mind." But the question may be asked, "Are the

cotton operatives, therefore, more efficient in body and mind than in 1856?" The writers say, "Yes." Part of the following facts, in their opinion, prove this.

TABLE V.—Average Weekly Wages of Cotton Mill Operatives, Manchester and Oldham Districts.

	1856 60 hours per week.		1880 56½ hours per week.		1905 55½ hours per week.	
	s.	d.	s.	d.	s.	d.
Scutcher	8	0	13	8	24	6
Cardroom Overlooker	28	0	38	6	50	0
Drawing Frame Tenter	8	0	14	8	21	0
Bobbin Fly Tenter	9	0	15	0	19	0
Spinners' Overlooker	26	0	40	0	50	0
Mule Spinners (average of fine, medium and coarse)	24	1	33	6	45	0
Mule Piecers (average of fine, medium and coarse)	8	3	10	8	14	10
Throstle Spinners	9	0	14	0	16	0
Doffers	6	0	9	0	8	0
Reelers	9	0	12	0	17	0
Winders	9	0	14	2	18	0
Warpers	23	0	33	0	45	0
Beamers	22	0	24	9	22	0
Doubling Overlookers	28	0	24	0	35	0
Doublers	9	0	12	0	16	0
Gassers	9	6	13	0	20	0
Weavers (average number of looms	11	2	15	3	24	0
Average of above 17 classes of Operatives	14	6	19	10	26	2
Comparison, calculated for number of hours worked	100		144		194	

The writers have shown that the operatives to-day have higher wages and more time in which to spend them. The commodities of life are also cheaper to-day than they were in 1856. (See Table VI., Page 131.)

House rents.—In 1856, the average house rents paid by the Lancashire cotton operatives, who represent about 78% of the

cotton operatives of the United Kingdom, were 3s. per week. Such houses consisted of two rooms downstairs and two rooms upstairs. In many cases they were single houses—*i.e.*, no way through, having one door only, and also one yard or court, &c., had to serve for the requirements of a whole block or row.

To-day, the average house rent paid is 6s. per week. Such houses consist of three rooms downstairs and two or three upstairs, with a private yard, &c., to each house.

TABLE VI.—Comparative Conditions of Cotton Mill Operatives in the United Kingdom.

Year.		1856	1880	1905
Total Number of Operatives Employed in Cotton Mills ..		380,000	486,000	523,000‡
Number of Half-time Operatives		15,000	51,000	21,000‡
Age of Children admitted to work Half-time		9 years	10	12
Age of Children admitted to work Full-time		13 ,,	13	13
		s. d.	s. d.	s. d.
Average House Rents		3 0	5 0	6 0
Paid by one of the Manchester Hospitals.	Meat per lb.....	0 7½	0 8	0 6
	Flour per doz. lbs.....	2 6	2 0	1 2
	Bread per 4lb. Loaf	0 8½	0 7½	0 5½
	Sugar per lb.	0 7	0 3½	0 1¾
	Tea per lb.	4 6	2 0	1 4
	Butter per lb.	1 2	1 0	0 11

‡ From latest published Blue Books, 1903.

How money is spent.—No doubt the greater desire for more clothing and more amusements takes much of the increased wages, as also the extra holidays allowed. The cotton operatives make full use of every holiday, as is well known from the amount of money saved in Lancashire towns in what are termed "going-off clubs"—but all the increased wages are not spent in

this manner, as the Returns of the Registrar of Friendly Societies show.

Thrift.—Since 1898 there has been an advance of two million members, and of £9,750,000 in funds of the registered Friendly Societies. Co-operative Societies have increased their membership by 250,000, and their assets by £13,500,000 during the same time. Post Office and other Savings Banks also show a large increase in depositors and deposits.

	Post Office Savings Bank.	Trustee Savings Bank.
In 1866 Deposits ...	£8,000,000	£38,000,000
In 1903 do. ...	£162,300,695	£59,352,927

Of course these figures apply to all inhabitants of the country, but the cotton industry, with 523,000 cotton operatives, make no mean fraction. In Lancashire, most industries, engineering included, being subsidary to the cotton industry.

Limited Companies.—Again the Limited Liability Act of this country has given workers a greater opportunity to invest money in industrial concerns (no return of the amount is available, but it must be large) and so become employers as well as workers, and they therefore take a keener interest in the trade and all that concerns its welfare. This fact is more noticeable in the cotton industry than in any other.

In 1856 there were about 2,000 private firms and no Limited Companies in the cotton industry of the United Kingdom. The first Limited Company, the Sun Mill, Oldham, was formed in 1858. To-day there are 890 Limited Companies in Lancashire alone, and the number is still increasing rapidly. During the last year 17 new spinning mills have commenced work, and 48 others are in course of erection. It is also estimated that 45,000 new looms have been put to work. (The writers are unable to give the number of private firms.)

The cotton trade, partly on account of the infrequent changes in the processes, lends itself admirably to the management and

working in the form of Limited Companies, hence their rapid growth.

Trade Unions.—Also the trade unions, of which there are about 110 in the various branches of the industry, prove to the writers that the cotton operatives are more efficient and thrifty. One trade union alone (the Amalgamated Operative Cotton Spinners) in 1901 had 18,500 members, an income of £90,320, and an expenditure of £52,650, and funds to the value of £378,800. These Unions have, in some degree, made their power felt, as some of the alterations in the Factory Acts which protect the operatives, have been brought about by themselves.

Factory Acts.—The Factory Acts of 1901 are a great improvement, so far as the operatives are concerned, in comparison to the Act which was in force in 1856. The 1901 Act now includes such clauses as follows :—

(1) Better sanitary conditions of factories and conveniences etc.
(2) Temperature of factory.
(3) Ventilation.
(4) Restrictions on cleaning with machinery in motion.
(5) Improved means of escape in case of fire.
(6) All accidents to be reported and investigated.
(7) Annual holidays fixed.
(8) Fitness of persons for employment.
(9) Humidity not to exceed a certain limit.
(10) Cloak rooms.
(11) Piece-work particulars to be given to every operative.
(12) Factory registers to be kept.

Education.—Again, the writers would point out the greater aim of the operatives to become more efficient by the attendance at lectures given in connection with the many Cotton Trades Mutual Improvement Societies, etc. These lectures, bearing on

various aspects of the subject, are held chiefly in the winter months, for the instruction of members, and visits are often paid to the works where the machinery, as used by the cotton industry, is made. Then there are the technical schools of to-day. Perhaps they are not taken advantage of to the extent they ought to be, but the numbers attending are increasing, and the average attendance at the cotton classes will bear comparison with any other.

The foregoing particulars show that the conditions of the cotton operative have vastly improved since 1856, and that he is more efficient in mind and body. The writers believe that this efficiency has been brought about by the opportunities given by higher wages and shorter hours. Higher wages and shorter hours have been made possible by the introduction of higher speed, more efficient and less costly machinery, which at the same time has considerably reduced the cost of producing yarn and cloth. Although no great changes in the principles of cotton machinery can be shown during the last fifty years, yet much has been accomplished by the engineers and machine makers of Lancashire and neighbouring counties, by producing more efficient machinery, to improve, perhaps indirectly, the conditions of the operatives of Lancashire's premier industry.

In conclusion the writers trust that they have been successful in bringing before the members and friends of this Association some instructive and interesting particulars of the Textile Industry, and that they have been able to demonstrate the important and foremost position it holds in this country, especially as regards the County of Lancashire.

The writers have experienced difficulty in obtaining really reliable information, especially in connection with the particulars concerning the earlier times reviewed, and they now desire to thank, amongst others, the following firms and gentlemen for information, etc., supplied:—

Messrs. Platt Bros. & Co., Ltd., Oldham.
Messrs. Brooks & Doxey, Ltd., Manchester.
Messrs. J. Hetherington & Sons, Ltd., Manchester.
Messrs. Joseph Stubbs, Manchester.
Messrs. The British Northrop Loom Co., Ltd., Blackburn.
Messrs. Henry Livesey, Ltd,, Blackburn.
Mr. A. Saxon (George Saxon), Manchester.
Mr. J. O. Cottrill (W. Ryder, Ltd.), Bolton.
Mr. Marshall, Manchester.
Mr. W. Tattersall, Manchester.
Mr. T. Crook, Burnley.
Mr. C. Clegg (Joseph Stubbs), Manchester.

APPENDIX No. 1.

The writers, knowing the large amount of interest taken in the subject of electrical driving in cotton mills, have (since the paper went to press) obtained the following particulars and estimates, which were drawn up just recently in connection with a projected cotton spinning mill of 80,000 spindles.

Three schemes were submitted, two of which, for electric driving, were drawn up by a firm of electrical engineers of high repute.

In No. 1 scheme, each machine was to be driven separately by an electric motor.

In No. 2 scheme, the machines were arranged to be driven in groups from line shafts, each shaft being driven by a large electric motor.

In No. 3 scheme, the usual driving by means of ropes from the fly-wheel of the engine to various shafts in the mill, was proposed.

In the copy of estimates given below, the cost of the steam engine or turbine is assumed to be the same in each case and therefore, not included.

No. 1 Scheme.	No. 2 Scheme.	No. 3 Scheme.
2 Alternators, 500 K.W. maximum, driven either by steam engine or turbine.. ..... £3,000	2 Alternators as for No. 1 scheme £3,000	Extras for Engine Rope Fly Wheel £500
		Shafting..... 4,000
		Ropes.... ... 700
320 Motors, Switchboard, Wiring and erection.... 16,050	Large Motors, Switchboard, Wiring and erection 10,700	Belting 1,500
Total.... £19.050	Total.... £13,700	Total.... £6,700

From these estimates it will be seen that there is a difference in cost of £12,350 between schemes Nos. 1 and 3.

Assuming that the cost of up-keep is the same in both types of driving, an assumption that the writers feel safe in making, from some data that has been obtained, this extra cost of £12,350 would mean an extra charge on the mill, per annum, of £617. 10s. 0d. for interest at the rate of 5%, and £617. 10s. 0d. for depreciation at the rate of 5% (which is considered very low) or a total of £1,235. Against this must be set the extra production of yarn obtained through the steadier driving, which the writers feel justified in placing at 7½%. This is equal to an addition on an 80,000 spindle mill of 6,000 spindles, or reckoning the mill to have cost £2 per spindle, an addition equal to £12,000 value. So that, taken on this basis, which is the only available one, it appears that when balanced up, the difference is very slight indeed, and does not justify the change in methods.

In giving these particulars, the writers must ask for the indulgence of all the members, as to their accuracy or otherwise.

The figures can only be proved, or disproved, by a mill being fitted up to the electricians specification and the returns being fully and freely placed before us, but up to the present time, no such information can be obtained from any source, owing either to want of confidence on the part of the electricians, or a desire to keep the information to themselves.

APPENDIX No. 2.

Re ELECTRIC DRIVING OF COTTON MILLS IN ITALY.

The writers have pleasure in giving the details referred to in the last paragraph of Page 119. The particulars have been obtained specially for insertion in this paper, through the kindness of Mr. Whitehead, of Manchester.

The 16 queries in the 2nd column were sent out, and the replies received from the management of four different mills are given in columns 3, 4, 5 and 6 respectively.

It will be noticed that the electricity is generated some distance from the mills, and that in each case they have the great advantage of water power. No reply has been given to query No. 7, *re* cost per unit, from any of the firms.

For Table of Returns see next page.

ELECTRICALLY DRIVEN

No.	Queries.	Replies from No. 1 Mill.
1	Is the electricity generated at the mill?	No. Power Station 3·1 miles away.
2	What type of prime mover—vertical or horizontal steam engine, steam turbine, water turbine, or gas engine, etc?	Hydraulic Power Plant.
3	Is dynamo direct-coupled or belt-driven?	Dynamo coupled direct to water turbine.
4	What type of dynamo—continuous or alternating, single or polyphase?	Alternating three-phase current 8,000 volts. 14 periods.
5	What is the Voltage?	8,000 Volts transformed in mill to 225 volts.
6	What is the total HP?	700 HP.
7	Cost of current per unit, or per HP?	Decline to give cost.
8	Cost for repairs, maintenance, etc?	Very little.
9	Is single-driving adopted, that is one motor to each machine?	Each machine has small motor, except cards and self-acting machines.
10	Or group-driving, that is one motor drives one shaft from which several machines are driven. If so, what is the average power of motors?	Cards are driven by a 10 HP motor for every 16 cards. Self-actings of 900 spindles each have 100 HP motor for every 10. Effective consumption = 6 HP for each mule.
11	Is electric driving found to be quite satisfactory?	Very satisfactory.
12	Is there any difference in the amount of yarn produced from machinery driven electrically and driven by steam engine and usual shafting, etc?	Production increased from 10 to 15%. Yarn is much better, as there is no atmospherical electricity generated by the friction of the belts.
13	What counts of yarn are spun?	From 100^s to 200^s.
14	How does cost of equipment of electric driving compare with steam engine and shafting installation?	Group driving costs a little more than driving by shaftings. Separate motors to each machine cost double the price.
15	When did this electric driving installation commence working?	In 1903, and has worked day and night up to present time.
16	General Remarks.	Naked wires are embedded in the concrete of the floors. Up to the present no weak places having been discovered, this scheme is considered safe and practical.

COTTON MILLS IN ITALY.

Replies from No. 2 Mill.	Replies from No. 3 Mill.	Replies from No. 4 Mill.
No. 1,200 HP generated at 2 miles away, and 960 HP at 2·8 miles away.	No. Generated 8·7 miles away.	No.
5 Water turbines.	Hydraulic turbine.	Water turbine.
Generators coupled direct to axis of turbine.	Alternator belt driven from turbine.	Coupled direct to the turbine.
Alternating three-phase current.	2 Alternators from three phase current.	Alternating three-phase.
3 Alternators give current at 3,000 volts. 2 alternators give current at 3,500 volts.	6,000 Volts.	3,000 Volts.
2,160 HP.	430 HP.	400 HP.
Insignificant.		
Almost all the motors are coupled to the line shafting	Group driving adopted.	Ring spinning frames are driven by separate motors.
2 Motors of 300 HP, 1 of 225 HP, 1 of 140 HP, 1 of 110 HP, and several small motors for a total power of 150 HP.	4 Motors at 500 volts. 2 of 160 HP each, driving the spinning and doubling machines. 1 of 50 HP, working only during the night for driving the scutchers, and 1 of 5 HP for driving the mixing room machine.	Other machines are driven in groups of 150 HP.
Quite satisfactory.	Are not dissatisfied with electric driving.	Satisfactory.
No difference in quantity of yarn.		No difference in quantity of yarn produced.
From 10s to 70s.	Average 26s.	From 20s to 32s.
960 HP in 1896, and 1,200 HP in 1904.	In 1905.	In 1904.

DISCUSSION.

Mr. R. Matthews in opening the discussion said that the paper was a most interesting one and in every way worthy to be handed down in the annals of the Association's Jubilee year. When it was considered that the wonderful pieces of mechanism, samples of which had been shown, were sold so cheaply, it was not surprising that machinists who supply cotton spinning firms could not earn dividends; there was something radically wrong which required examination.

The references to the cotton industry were interesting, but being himself engaged in the iron trade he had thought there was no trade like it. His firm alone, and they were only one out of many, paid wages equal to 25% of the wages paid by the cotton industry.

One thing brought out very notably was the improvements that the operatives had gained during the last fifty years, but he was afraid the workers did not appreciate these as they should do. It did not matter what new machine was brought forward workmen would not endeavour to allow it to do its maximum output. No doubt the same applied even in the cotton trade, for instance, in the Hyde district there had been several strikes due to the introduction of the Northrop loom.

According to Table IV., in 1880 215 millions of pounds of yarn were exported, but 25 years after, viz., in 1905, it had dropped to 205 millions. These figures were very forcible, and required some further explanation.

He was sorry the Authors had not got the expected information respecting electrically driven mills; but in respect to the 7% increased efficiency, which was said could be expected from steadier turning in electrically driven mills, steam engines could

be made to also give equally steady turning for a very little extra cost.

Mr. HEAP (visitor, Swan Lane Mill, Bolton) stated that without some preparation he was not in a position to give any views on the driving of cotton mills. If the paper required elaborating at all as to what was now being done in mills, there was no one better able to elaborate it than Mr. Cook himself.

Mr. JAS. WHITEHEAD (visitor, Acme Mill, Pendlebury) said that according to the paper the bulk of improvements in cotton machinery were made prior to 1856. No doubt these were the essential improvements, but many others, although only perhaps minor ones, had been made since then, which had added very materially to increased production. After the regulator there were the great improvements of the carding engine and its clothing, the grinding arrangements for same, the improvements in the steel rollers, the better fluting of them, and the better covering of the leather rollers, the balancing of flyers and spindles throughout the mill, the improved facilities for lubrication, and the vast improvements of the general make of the machinery, had all helped to bring about this increased production.

In respect to his electrically driven mill, this was running and giving satisfaction in every way, and he saw no reason why it should not; the driving was exceedingly steady, and there had been no trouble with it from the start. The largest motor which was running was 200 HP, and seven-eights of the load was on it. In his opinion, electrical driving would come more to the front, and mechanical engineers would have to give it more consideration in the future than they had in the past.

In the Appendix had been given three different schemes of driving. The first scheme was too expensive; unless motors

could be produced for a much less price, it would not be practicable to put a motor upon every machine. To start a ring frame required 50% more power than was required to keep it going, so that if this scheme of driving every machine by its own motor be adopted, there would be required 50% more motor power installed than was actually required to drive the mill; consequently, a proportionate increased outlay on cables. These increased costs were so great that the first scheme could not at present be adopted.

The system adopted at his mill was similar to the second scheme, the motors being put on line shafts. The prices given seemed exaggerated, but he was not prepared to give any definite figures at present.

In respect to No. 3 scheme, the difference in cost between the electrical equipment of a mill and the mechanical equipment with a steam engine was not so great as generally expected, and the figures which were given for this scheme were not as reliable as at first sight appeared.

Mr. Sam Boswell remarked that the authors were scarcely correct regarding type and diameter of boilers generally in use in 1856. About this time, however, and even later, Engineering Professors, and most Text-Books, erroneously described the "Lancashire" boiler as the "Two-flued Cornish," a palpable misnomer, as the number of flues was the dividing line between the Cornish and the Lancashire. Even these distinctions vanished when the fire-grates were taken out of the flues, and boilers fired under the bottom, when they were then called "single" or "double" flued boilers. The "Lancashire" boiler was without doubt in very general use previous to 1840, except at collieries, where egg-end boilers, and small installations and waterworks where "Cornish" boilers were in use. So generally had it been adopted, that from 1841 to 1844, Fairbairn saw the

possibilities of higher pressures, and spent much time and thought in improving it, particularly by strengthening the flue tubes by adopting T seams. The bowling hoop was introduced about 1849, the Petrie pocket, Adamson flange, and Galloway tube about 1851.

Speaking from his own experience, in 1862 90% of the boilers at the various industrial establishments were of the Lancashire type, and very many of these had been in use 20 to 30 years to his own knowledge.

As regards diameter, boilers up to nine and ten feet were not uncommon, particularly in East Lancashire, one old Burnley firm making a speciality of nine feet diameter boilers, some of which had three flues in. In 1868, however, when pressures were rising, and boiler making appliances were not as perfect as at present, various authorities, particularly the late Mr. Lavington E. Fletcher, favoured boilers 6ft. 6in. diameter when boilers at 70lbs. and upwards were wanted, while at this time a Manchester firm made two boilers 26ft. by 12ft. diameter which he thought were even yet at work. There seemed, however, to be a lack of confidence in the boilermakers of that day, and the engine builder always put the onus of want of pressure on the boilermaker.

Now, however, the engine builder knew he could get whatever pressure he required by asking for it, and he need not depart from the Lancashire type which was undoubtedly the most economical.

He (Mr. Boswell) fully appreciated the value of the paper. There was, however, one little surprise in it, that in the description of the modern plants the Water Tube boiler had not even been mentioned.

Mr. G. D. Seaton (Visitor) thought it unfair that turbine makers should be included in Mr. Cook's remarks respecting

electrical engineers withholding information. At Rugby, at Messrs. Willans & Robinson, they were only too pleased to see anybody, whether competitors or not, and show them round the works and give them every detail.

The 750 k.w. turbine at Droylsden which had been mentioned was not yet running, and therefore no figures were available. The makers had made the request to the owners of the mill that when the turbine was running the whole installation should be handed over to Mr. Michael Longridge for him to test and get reliable figures. The installation was a very interesting one from several points of view. Babcock & Wilcox water tube boilers were being used, the turbine was being made by Willans & Robinson, the alternator by Dick, Kerr & Co., and the whole of the electrical equipment by the British Thomson Houston Co.

Personally he was of the opinion that the electrical driving of mills was going ahead.

Mr. A. Saxon said he thought Mr. Whitehead had "hit the nail upon the head" in connection with the driving of mills electrically. Mr. Metzger, in a recent paper on Electrical Developments, had held out the hope that all the line shafting in electrically driven mills would be dispensed with, and that if only electricians could have the arranging of a mill entirely in their own hands, without architects or mill people interfering with them, all would be well. It might be so if the capital could be raised for the electricians, but in the Appendix it stated that almost three times the capital was required to drive a mill electrically, with separate motors to each machine, than required for a steam engine driven mill. The obtaining of this capital would be very difficult, as had been proved in this country in connection with the weaving industry with regard to the adoption of the Northrop and similar looms, the fact being

that ordinary looms were being put in to-day because they could be obtained at so much less capital cost.

The diagram illustrating the various operations which yarn passed through before it got into cloth was a splendid one, but anyone not an expert would imagine, without some further explanation being given, that all cotton to be woven into cloth had necessarily to go through the gassing frames and all the other processes described on the diagram. Possibly the authors could give a few more explanatory notes on this point.

As a matter of general interest, he mentioned in connection with driving of mills, that he had recently asked for some information about the electrical driving of some mills at New Bedford, U.S.A. He went through these mills two years ago, and at the time tried to obtain some idea of the cost, but was unable to do so; he had recently received a letter from a correspondent saying that there were now three electrically driven mills in operation in New Bedford, but they were not yet dividend paying concerns.

In England, in the Lancashire district, the people were progressive; they must have been to have had the 50 years' progress which had been described in the paper. He hoped that the progress would continue on whatever lines proved to be the best and cheapest. Mr. Whitehead advised mechanical engineers to keep their attention fixed on electrical means of driving. He did not know what Mr. Whitehead's views would be when he knew the cost of the current for his mill when the whole plant was in operation, but hoped that the enterprising gentlemen Mr. Whitehead was connected with in inaugurating this new departure, would be justified in the expenditure. Someone had to run risks, and make a test as to whether progress was right in this or some other direction, and therefore they were to be congratulated in taking such a step.

Mr. THOMAS ASHBURY stated that though he was an outsider of the Textile Industry he had been very much interested by the paper, and felt under the deepest obligation to the authors for the very great care given to it, and the accuracy obtained so far as their information had been available.

He thought that instead of a radius of 30 miles round Manchester, a radius of 45 miles should have been taken when making a comparison of the inhabitants in that radius with the inhabitants of the metropolis.

Taking a triangle with Stockport at one angle, Preston at the second, and Leeds at the third, covering about 113 square miles, in that triangle would be obtained the densest and largest *manufacturing* artizan population to be found on the same area in any part of the world.

Nothing had been said in regard to the *Hand Loom* which preceded power-driven textile machinery. The hand loom weavers in Nottingham at the present time were experiencing just the same difficulties which 50 or 60 years ago were experienced in this district. In the census of 1901 about 300 hand loom weavers were recorded as being in West Yorkshire, and 500 or 600 in Lancashire; but when the next census came in 1911 he thought the hand loom weaver would be nearly extinct.

He well remembered the introduction of the "Heilman Comber." Joshua Heilman had spent a fortune and an enormous amount of time in his endeavours to perfect the Comber. After almost ruining himself in his attempts, he returned to his native home in Alsace, and on one occasion a bright idea struck him as he saw one of his daughters combing out her hair, and noticed the care in which she combed out the ends, skein after skein, till the hair was thoroughly combed and all the stray hairs brought into position. Working on the same principle he set to work and perfected the Combing machine,

and finally presented it in the form in which it acts with almost the delicacy of touch of the human fingers.

In the 1887 Manchester Jubilee Exhibition there was a splendid portrait of Joshua Heilman, by A. Elmore, R.A., showing the inventor studying intensely the movements of his daughter's fingers in the combing out of her locks.

Mr. William Ingham thought the paper had some very remarkable features, and was most interesting from every point of view, but especially so in its economical and social aspects. It would be noted that wages had increased 94% in the period under review, the hours worked were shorter, and food was cheaper. These points could not be too strongly insisted upon, because, at the same time, the status of the operative had been improved; and the fact that wages had increased, and the working hours had been shortened, meant greater producing power and lessened cost of production. If these results were compared with what obtained in other countries, say for instance, Russia, where food was dearer and wages low, there was the remarkable fact that the more the cost of an article was cheapened, the better was the chance of competition, and the greater the progress made.

He did not agree with Mr. Cook that youths in the textile industries were more diligent, or more studious than engineering apprentices. If the number of workers in the cotton trade were compared with the numbers employed in the engineering trades, it would be found that it was only the intelligent few in each who took to studying to improve themselves, and this rendered it possible for those who were anxious to rise, and who were willing to devote their leisure hours to self-improvement, to attain positions of influence and authority in any particular industry or trade.

Mr. William T. Stubbs thought that one conclusion that would be come to was that progress continued to be made in this country. It was sometimes said that England was being played out, but taking the figures given in the paper, this was not the case, as from 1856 to 1905 there had been the large increase of 20 million spinning spindles, and although yarn exported had not increased in the same proportion in pounds weight, it had to be borne in mind that in this country the tendency was to produce finer counts and better qualities. There was no doubt that in England the cotton industry was in a highly efficient state.

A point which was to the credit of machine makers, was that the bulk of textile machinery used was still made in this country. Although in the United States a duty of 45% had to be contended with, certain textile machinery for that country was still bought from England, as was also the machinery used in the bulk of the cotton mills on the Continent.

With regard to the electrical driving of mills, this was increasing all over the world, particularly in those countries where there was ample water power. He had been in some of the finest mills in Italy during the last twelve months. There the mill-owners did not go to the expense of machinery for generating their own current, but bought the electricity from a public Company at very low rates. Many of the best mills in Italy and Switzerland were now being driven electrically. In England, where there was no water power, a start had to be made with coal, and he was of the opinion that if electrical current could be got at ½d. to ⅝d. per unit, taking into account the fact that no provision had to be made for an engine house and engines, the saving in shafting, and the cheaper buildings that could then be put up, electric driving was quite as cheap as by driving by steam engines.

Mr. Bingham said that the chart of the processes which yarn passed through would be very useful, but the part marked "weaving" showed arrows proceeding from only the warping section and winding; it did not show anything coming from the mule spinning or ring spinning in the shape of mule weaving or ring weaving.

With respect to the British Cotton Growing Association, a mill manager recently stated that his mill wanted everyday the cotton produced from 500 acres, meaning that for one mill he wanted the products of 2,500 acres per week. That would give an idea of the magnitude of the work before the British Cotton Growing Association.

The paper seemed hardly complete without showing the single winding frame. This was very largely used in America, and was now being gradually adopted in some mills in Lancashire.

The President (Mr. Robert Matthews) stated that the question of electrical driving, to his mind, was a very important and serious one. A few years ago he gave some assistance in getting the Lancashire Power Company's scheme carried through, he was not a shareholder, and was purely independent. He gave evidence before Parliament, and finally the Bill was got through, subject to serious restrictions as to supply, in spite of the amount of money spent by the Manchester Corporation in opposing it. He had seen only a few weeks since that the Corporation had decided to oppose some further Bills in the same way. All engineers, and electrical engineers in particular, should protest against this squandering of ratepayers' money. Electrical driving, to his mind, was the right thing to adopt, but it ought to be generated at the pit mouth, and instead of having to carry a train load of coal the power could then be carried away by a cable. All smoke would then be abolished in towns, and living arrangements would be altered and be vastly

superior to the present, but if this extravagant municipal trading continued it would be disastrous for the country.

If the progress of the country was to be improved, then it was highly essential that power should be obtainable at the lowest possible cost. Collieries were close to Manchester where the power could be readily generated and thus valuable space saved which was now occupied by many power stations. He hoped those interested in municipal affairs would use their best endeavours with a view of trying to improve the status of the electrical generating stations and so getting the power as cheap as possible; at present with municipal working everything was charged almost double with a view to cutting down the rates, when the rates were reduced people's attention was not drawn to them, but if the gas, electricity, and other departments were only to charge the bare net cost the apparent rates would rise to a very high figure and attention would be drawn to them. That was a matter which was not looked into in a sufficiently serious manner.

In moving a vote of thanks to the authors for the paper, he added that he thought electrical driving would eventually become general, but at present, whether electricity was made privately or bought, it was much too dear.

Mr. W. H. Cook in replying to the various speakers' remarks, said that the President had referred to the Table which showed that the yarn exported from this country had fallen. Unfortunately that was the case; the spinning side of the cotton trade had been a declining one, and very decidedly so, up to the last year, but he felt certain that before another two years had passed this loss would be reduced because of the many new mills which were being put up every year.

He was disappointed with the remarks of Mr. Whitehead, who had evidently been captured by the electricians, and would give no information respecting his electrically driven mill.

The 12ft. diameter boilers mentioned by Mr. Boswell were extraordinary, and must have been made for a scientific experiment.

In respect to Mr. Seaton's statement that his firm would have given any required information, Mr. Stubbs had sent a tabulated list of questions to the whole of the leading electricians in England and abroad, but they were returned without a single note of information on them. One of the firms wrote saying that in view of the fact that the electrical equipment of textile mills was then only in its infancy, and seeing that the only mill electrically equipped throughout had only been running one month, any figures they could give would not have full weight attached to them; therefore, they thought the authors' purpose would be better served by writing to firms whose names they gave and whom they thought had considerable experience in electrical driving and would furnish the necessary information. The firms mentioned, however, had already been written to, but they had not given the authors' any information whatever.

The diagrammatic sketch as printed was somewhat confusing, but this was due to being unable to get the lines printed in different colours.

He had great pleasure in thanking them for the kindly way they had received the paper.

Mr. J. H. Stubbs remarked that Mr. Cook had replied to all the questions which had been raised, and certainly taking them as a whole there was little to reply to. As Mr. Cook had mentioned respecting the Acme Mill, it was exactly what had been anticipated, and they never expected to get any information.

Mr. Seaton had mentioned in respect to the turbines that information could be got; but he had written to two of the best makers of turbines in the country and their replies had been

that they would not give the information. He had not written to Mr. Seaton's firm of Messrs. Willans & Robinson, Limited.

Mr. Cook interposed with the remark that in fairness to Messrs. Willans & Robinson, Limited, they had given him information in respect to turbine matters, and more than that, they had showed him that they then had 37,000 HP on order on their books. That was eight months ago; this firm also offered a guarantee as to the steam consumption of the turbines.

Mr. Stubbs, continuing, said that they sent out a tabulated list of questions to the largest makers in the country, and the most widely known people returned them saying that they could not answer them. Probably the questions were too technical for them.

Respecting Mr. Boswell's remarks on the subject of boilers, they had obtained information from one old book which gave 25ft. as the longest boiler in use, 6ft. as the largest diameter, and 25lbs. as the highest pressure. Another book gave a little higher pressure and therefore the authors thought that if they mentioned 20 to 60lbs. pressure they would be on the safe side. These books also mentioned that the Lancashire boiler was just being introduced, and Mr. Boswell confirmed this by saying that it was about 1860 when they were first properly introduced into this district.

He could not see why power should be converted into electricity, and then the electricity converted back again to power on to the machines; whereas, with an engine of good class the power could be taken direct from the engine on to the line shaft. This latter, in his opinion, was a much better arrangement.

It had been said that in order to bring the paper up to date mention should have been made of the winding frame with a single row of spindles. This reference had been left out,

however, as it was not considered to be up to date, it was an old-fashioned idea copied by the Americans, and was now being brought back to England.

He thanked them in conclusion for their kindly reception of the paper.

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13 Plates follow illustrating this Paper.

BIBLIOTHÈQUE DE PARIS

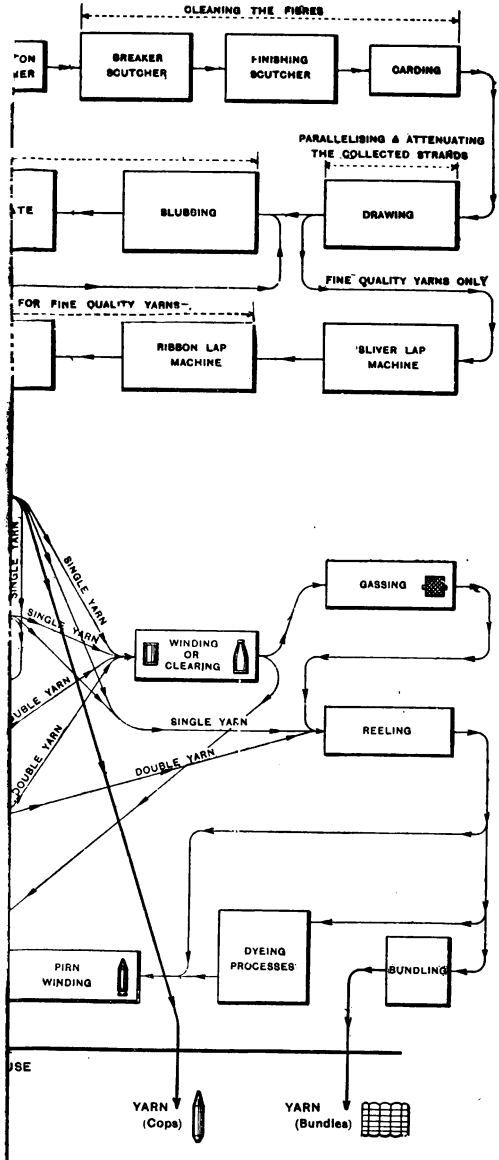
Plate XII.

Fig. 23.—Mill, 1905.

UNIV. OF MICH.

Plate XIII.

INDUSTRY.



the Manufacture of Cotton Yarns or Cloth.

UNIV. OF MICH.

HARBOURS, DOCKS,

AND THEIR EQUIPMENT.

READ SATURDAY, 24TH MARCH, 1906,

BY

Mr. W. HENRY HUNTER,

M.INST.C.E., M.Am.Soc.C.E.,

(MANCHESTER).

Comparatively slight consideration will show that our manner of life in the City of Manchester in the Jubilee year of this Association, our interests and aspirations, the character of our food and of our clothing, have all been largely determined for us by the operation—through periods so indeterminate as to be beyond measurement—of the great forces of nature, now in the way of devastating catastrophe and overwhelming cataclysm and now in that of slow but certain re-adjustment and recovery, by means of which the form of the earth has been moulded, existing conditions have been developed and the environment which has made us what we are, and our circumstances what they are, has been shaped and constituted.

The business of the historian, whether he deals with upheavals of a geological or of a political sort, is to narrate for our instruction the processes and the methods by which this environment has become what it is; the business of the philosopher is to discover, or failing powers of discovery, to imagine, and to describe the underlying causes which have given rise to the effects narrated by the historian.

Both classes have done their best, the results are written for our learning, and it is necessary that we as engineers should make ourselves acquainted with them. But our own business is of a different sort, for the duty which lies upon us is first, to discern points and features in which the environment which nature has provided may be improved; secondly, to devise methods and appliances by means of which the improvement may be effected; and thirdly, by means of these methods and appliances to give the improvement concrete shape and practical and operative form, so that we may discharge our duty to our day and generation.

In the district of which Manchester is the centre, something has been accomplished in this respect. The operations of nature did much for and gave much to the site of the city, but did not do everything, as they left the site high and dry, like a stranded ship, far from the life of the sea; so that it came to pass that the great manufacturing and commercial community, which in process of time clustered on and round the site, was left—so far as access to the high seas was concerned—at the mercy of a neighbour whose interests were often diverse from and sometimes adverse to those of the citizens of Manchester and of their fellows in the manufacturing districts of Lancashire.

An effort, which was remarkable for its loyal combination and for its self-sacrificing determination, was made to remove this disadvantage. The effort was met with the most strenuous opposition by many interested parties, on the part of which a determination was evinced which was almost if not quite equal to that of the supporters. The struggle was as fierce as it was protracted, but the result was inevitable, for the effort was in the line of true progress; and Manchester which natural operations left in the position of a city far inland, has through the engineering operations with which all are familiar, achieved a

position which she had been denied by nature, has obtained direct communication with the sea, has become a port for ocean-going vessels, has already secured a high place amongst the ports of the United Kingdom, and will year by year and decade by decade improve upon that place.

The achievement has had many beneficent and far-reaching consequences, to one of which only may reference be made here, viz., that as a consequence of the conversion of Manchester into a sea-port, the Manchester Association of Engineers has been led so far in the way of interest in matters connected with "Harbours, Docks, and their Equipment" as to desire that a communication bearing upon these matters should find a place in the Syllabus of the 50th Discussion Session of the Association.

All well-wishers of the Association will desire that the interest thus shown may grow and increase, because interest in means and methods of dealing with the shipping trade will, the subject having a fascination of its own, inevitably lead to interest in shipping and in routes and lines of trade; and thus the outlook of the Association will be enlarged, the sympathies of its members will be widened and the members themselves rendered more capable of taking a due part in the world-wide struggle for commercial supremacy which is in progress around us, and through which economic conditions which once appeared to be established and immovable have been shaken to their base, so that it is more than ever true that

"The old order changeth giving place to new."

In connection with this awakening interest in maritime matters, it may be useful to observe that the impression which obtains amongst British people as to the antiquity of the concern in and with such matters by the British nation as a whole, has no foundation in fact, because the truth is that British interest in shipping and in terminal accommodation for shipping

is of very modern growth indeed, while British effort in the way of engineering operation is still more modern in its developments and achievements.

This will appear the more remarkable when the insular character of the kingdom is remembered, and when it is further remembered that the nation was not without the examples and object lessons which were afforded by the successful and advantageous proceedings of other nations.

More than 2,500 years ago Phœnician engineers built breakwaters, constructed moles and formed safe and convenient harbours in which they sheltered their galleys and their sea-going ships. When the Phœnician power, broken at the destruction of Tyre, finally fell in the fall of Carthage; the Romans took up the work. They in turn were followed by Byzantines, Venetians, Spaniards and Portuguese, Germans and Dutchmen, who all built and sailed ships, and moreover built and equipped harbours and docks for the ships and for their cargoes.

Through this long stretch of history England remained so supine and inert that when the awakening came, in the time of the Tudor monarchs (Henry VIII. in his establishment of the Trinity-house, laid a foundation for maritime greatness upon which Elizabeth's great sea-captains began to build) and shipping guilds and corporations began to come into being; there were no English engineers, even of the most elementary or rule-of-thumb type, available for the improvement of the natural facilities of the country or for the provision of the tiny harbours required to cradle the infant commercial navy of England, so that the harbours of the 16th century (when harbour construction began here) were the work of foreign engineers, except indeed under circumstances of such stress as those described by Baines the historian of Lancashire as having arisen in 1561, when the "ancient haven" of Liverpool was

totally destroyed by a destructive storm and when the burgesses themselves set to work with spirit and in a short time constructed a "new and better haven."

English harbour construction may therefore be said to have behind it an authenticated history of some 3½ centuries. Dock construction has a shorter record as the first dock built in this country was the basin formerly known as the Howland Dock, (opened in 1660,) which was formed at Rotherhithe on the Thames, out of an excavation originally intended for a river diversion, and which is still in use as a part of the Greenland basin of the Surrey Commercial Docks. The next English dock was the old dock in Liverpool which occupied the site on which the custom-house now stands, and which was opened about 1708 or 1709.

From the 18th century onward the British shipping interest as an adjunct to the great commercial and manufacturing developments of the United Kingdom grew rapidly, expanded by leaps and bounds. Not only did the number of British owned ships increase year by year, but a steady growth took place in the size of the craft in use, until the English nation, apparently out of the race altogether for so long a time took the first place in that race, and ultimately left all other competitors so far behind that there was practically no second. This proud pre-eminence was due to several far-reaching causes, but an essential factor in the success achieved was the fact that shrewd and far-sighted men in this country recognised the possibilities which were presented to them in new methods proposed for the construction and for the propulsion of their vessels, that is to say, in iron-built and steam driven ocean-going ships, as enterprising English merchants of the early part of the 19th century built iron steamers, found for them immediate and successful employment, and so secured the trade while their competitors abroad waited and wondered whether iron-built

hulls would float and steam driven machinery withstand the rude shocks of deep sea waves.

The progress of the shipping interest led to consequent and concurrent advance in harbour and dock construction.

The Thames furnished up to a certain point a typical case in point. Following the West India Docks of 1802, came the London Docks in 1805, the East India Docks in 1806, St. Katherine's Dock, 1828, Victoria Dock, 1855, Millwall Docks, 1868, Albert Dock, 1880, and the great Tilbury system in 1886.

Developments similar in kind, and in some cases even greater in extent, took place on the Severn, the Mersey, the Clyde. the Forth, the Tyne, the Wear, the Tees, the Humber, the Wash, indeed on nearly all the estuaries and indents on the coast. It is impossible to follow the details of the advance, but a note should be made *en passant* of the exceptional rate of the advance which has been made and the unprecedented character of the progress which has been maintained during the half century covered by the existence of the Association, both in respect of the shipping of our country and of the terminal accommodation without which the shipping could find no home in our land.

In 1855 the average gross tonnage of all vessels launched during the year was for sailing vessels 200 tons, for steam 450 tons, the total tonnage launched being over 200,000 tons. In 1905 the respective figures were for sailing vessels 150 tons, steam 2,000 tons, and total 1,698,000 tons.

In 1855 the total tonnage of the mercantile marine of the United Kingdom was about 5,000,000, in 1905 it had grown to 17,000,000. The nature of this growth will be better appreciated if it is remembered that at the end of the 16th century the total tonnage of English and Scotch shipping was under 20,000 tons. Two centuries and-a-half were therefore required for a develop-

ment of a trade of 5,000,000 tons which in half-a-century increased by no less than 12,000,000 tons.

In 1855 the largest and most powerful vessel engaged in the North Atlantic trade was the iron-built Cunard boat "Persia." The "Persia" was a paddle-steamer of 3,300 tons gross, she was 360ft. in length, had a beam of 45ft. and steamed at 12½ knots.

The largest vessels now actually engaged in the same trade are the "Baltic" of the White Star Line, and the "Caronia" and "Carmania" of the Cunard Line. The gross tonnage, length and beam of these vessels are as follows, viz.: "Baltic," 23,876 tons, and 709ft. 2in. × 75ft. 6in., "Caronia" and "Carmania" 19,560 tons and 650ft. × 72ft. 2in. Even these colossal steamers will be dwarfed by the two new Cunarders, to be launched this year, which are being built one upon the Clyde at the works of Messrs. Jno. Brown & Co., and the other on the Tyne at Messrs. Swan & Hunter's yard, and of which the gross tonnage will be 28,830, the length and beam 785ft. and 88ft., and the loaded draught of 37ft.

While dwelling upon these sensational figures it is only right that we should observe—and the observations will serve to illustrate the complexity and the inter-dependency of modern existence wherein it may so truly be said that "none of us liveth unto himself, and no man dieth unto himself"—the development which has taken place would have been impossible apart from modern steel makers; from men like Martin and Siemens, or Bessemer, or Thomas and Gilchrist, who, in the mild steel of great tensile strength with which we have all become so familiar, provided a material which rendered the construction of these monsters of the deep commercially possible; or from modern engine builders, a brood too numerous even to select names from; who have restlessly thrust forward improvement upon improvement, invention upon invention; until after fiercely

hustling one another in the race for efficiency for the combination of increased power with diminished fuel consumption, they have supplied the shipbuilders with means of mechanical propulsion such that great vessels are to-day being driven through the waters of the great deep at the rate of 23 knots an hour.

Yet how recent all these epoch making improvements have been. The half-century with which we are particularly concerned had sped half of its course before steel began to appear amongst the materials of which ships are built, and had almost entered upon its course before the compound engine was introduced into the mercantile marine. Steel-built ships first appeared in the list in 1880, while in 1854, John Elder fitted for the first time, a successful set of compound engines into a boat which he had built in his yard upon the Clyde. Twenty years later, Dr. A. C. Kirke fitted a vessel named the "Propontis" with triple expansion engines, with results which, owing to the failure of the boilers used, proved to be far from encouraging; and it was not until 1882, when the same engineer fitted a similar set of engines* into the "Aberdeen" and supplied them with steam from boilers of the present common Scotch marine type, with a pressure of 125lbs. to the square inch; that it became evident that real advantage had been gained and that it began to appear that mild steel and multiple expansion engines would revolutionize shipbuilding and would transform the conditions of modern life.

We have seen the revolution effected, in part, at any rate, and have witnessed the beginning of a great transformation; but the end is far from being in sight, and while we know in part the things which are, we cannot prophesy even in part concerning the things which those who come after us will see, and which may furnish interesting topics for retrospective

* Illustrated in "Engineering," vol. 33, page 528.

narrative and discussion when the Centenary of this Association is celebrated.

Competent authorities are of opinion that the limit of improvement in reciprocating steam engines has been reached, and advocates of steam turbines on the one hand and of internal combustion engines on the other, are beginning to make their voices heard in the strife of tongues and of theories, and are keenly anxious for opportunities for putting their theories to the touch of practical working—at some other person's expense—and of showing in this way lines upon which still further advance may take place and still greater advantage be gained.

Members of the Manchester Association of Engineers should see to it that they take a fitting part in this struggle lest they be thrust into the ignoble place of mere lookers on, as "dumb driven cattle," as the American poet has it. It should therefore be recognised that, if it be true that the limit of improvement in multiple expansion engines has been reached and that the present very imperfect machine can be carried no nearer to perfection so far as the engines of sea-going vessels are concerned; the multiple expansion engine is doomed, that it will soon be moribund, and sooner or later, will be dead.

Through the enterprise of an eminent man who has just passed over from us to the silent majority—the late Lord Inverclyde, the chairman of the Cunard Co.—a very practical opportunity has been afforded for putting to a crucial test the comparative advantages and disadvantages of marine steam engines of the most improved construction and of steam turbines, for of the two great sister ships which have just been placed by the Cunard Co. on the North Atlantic trade, one the "Caronia" is fitted with quadruple expansion engines, and the other, the "Carmania" with Parson's steam turbines. Every engineer will watch the working of these two steamers with more than ordinary interest, and will wait with something like anxiety for

the comparative results which the Cunard Co. will assuredly declare *pro bono publico.*

The effect upon harbour and dock construction in this and in other lands of the marvellous and unprecedented increase in the size of ocean-going ships which has been sketched in so outline a way in this paper, needs no description, it is so apparent to every one. In 1855 the depth of water upon the bar of the Mersey, 11 miles from the Rock Light, which governed the draught of all the vessels trading to and from Liverpool was 11ft. From 1855 to 1890 the depth fluctuated from 7ft. to 17ft. according as the effects of wind, wave and flood were favourable or otherwise, the channel over the bar having, owing to an almost superstitious dread of interference with the bar's malign powers of obstruction which possessed the authorities of Liverpool, been severely left to itself and to its own devices.

Fortunately for everyone, circumstances upon which it is unnecessary to dilate here proved too strong for the Mersey Docks and Harbour Board, and operations, first of a tentative and afterwards of a more determined sort, were taken in hand for the removal of the bar by means of hydraulic dredging. These operations (which were begun in 1890) proved, under the direction of the present engineer-in-chief to the Dock Board, to be entirely successful. The depth which was gained by the working of the sand pumps has been maintained by the same means, so that the present depth in the channel where the bar used to be is 27ft. below low water of spring tides; a quantity of some 35,000,000 cubic yards of sand having been removed from the site of the bar between 1890 and the end of 1905.

In 1855 the depth of water at Sandy Hook, a most expressive name, at the entrance to New York harbour was little more than 20ft., and the channel on plan resembled nothing so much as a dog's hind leg, looked at in side elevation. At the present time dredging and other operations of great magnitude are in progress,

the "hook" is being done away with, and the channel is being straightened and deepened so fully as to give a depth of water of 40ft. at low-water of spring tides, and is thus being rendered fit for use by the very largest of the steamers hereinbefore referred to.

Harbour works of the same class, though not of altogether such great capacity, are being either constructed or enlarged all over the earth; to describe them a book would be required and not a paper, while similar activity has been displayed in dock formation and enlargement, particularly during the last quarter of a century.

One example of the very recent increase in the dimensions of locks and dock entrances which has followed the growth of naval architecture may be of interest, as it is from the writer's own personal experience. In 1887 when the question of the dimensions of the locks on the Manchester Ship Canal was being considered, it was found that a lock 600ft. × 65ft. × 26ft. would be sufficient to allow any vessel afloat, except one, to pass. The exception was the s.s. "City of Rome," belonging to the Inman Line, which although only 586ft. between perpendiculars, had an overhang both fore and aft such that a length of lock of 627ft. would be required for her passage. The "City of Rome" was an admirable example of almost everything which a large steamer ought not to be, and it was finally determined to leave the eccentric vessel out of consideration and to build the locks 600ft. long, and so the locks were built. In 1905, the Board of Consulting Engineers formed by the President of the United States, for the purpose of considering all the engineering questions concerning the Panama Canal, determined after a full investigation, that the locks on that great inter-oceanic waterway, should, in order to meet the growth in the size of steamships, have a length of 1,060ft. a width of 100ft. and a minimum depth of 40ft., or an increase of

capacity of over 400%, as compared with the capacity of the larger locks on the Manchester Ship Canal.

In retrospective papers of this sort the employment of figures is essential in order to enable the mind to measure the character and the extent of the improvement which in any given period may have taken place in the conditions of human existence, and to gauge the degree of success which has attended the efforts of the human race to control and to direct into beneficial channels the operation of natural laws; but when figures are extended into columns and into pages they become a nightmare-like burden, they become statistics, and as such find a fitting place in appendices which are never regarded, and in addenda which are never read.

In order to suggest the extent of the development which the half-century has witnessed, and at the same time to avoid the statistical nightmare, a very few figures relating to the leading features of the older ports in this country, viz.: London, Liverpool and Bristol, may be added here to the particulars already included in this paper.

The features referred to are :—(1.) Areas of water space in docks. (2.) Areas of land space around docks. (3.) Lengths of quay frontage. (4.) Greatest depths on entrance sills. For London in 1855 the water area of the docks was 290 acres, while the area of the adjacent estates, including quays, roads, railways, etc., was 754 acres. In 1905, the respective areas were 659 acres and 1,726 acres. In 1855, the length of quay frontage was 16 miles, in 1905 29 miles, while the depths upon the sills of the entrance locks were in 1855, 28ft. below high water of spring tides, in 1905 44ft. below the same datum.

For Liverpool (in which Birkenhead is included), the comparative figures taken in the same order and at the beginning and ending of the same half-century were 209 acres and 291

acres; 569 acres and 1,108 acres; 16 miles and 85½ miles; and 28ft. and 41ft. 7in.*

For Bristol (including Avonmouth, Portishead, etc., and also including the new docks now in course of construction) the figures are 85 acres and 24 acres; 144 acres and 735 acres; 1⅗ miles and 5 miles; and 30ft. and 46ft.

It is not necessary to remark upon the significance of these particulars; the emphasis which has already been laid upon the phenomenal growth of British shipping during the fifty years with which so many of us have had personal acquaintance is to some extent reflected in them, and would become more accurate in proportion if taken conjointly with the figures relative to the many new ports, such as Manchester, Barry, Milford, Heysham, etc., which have come into being during the period, and to the many others such as Southampton, Cardiff, Swansea, Glasgow, etc., which have sprung from insignificance to importance, and of which the names, once only of local fame, are now of world-wide renown.

As one example only of the work which has been accomplished, and of the results which have been achieved in these modern ports, the figures relative to the most modern of them all, to our own port of Manchester, will serve. Omitting reference to the docks connected with the Bridgewater Canal, which serve an inland barge traffic and not an oversea shipping trade, the leading features of the Manchester Docks are at present as follows, viz.:—Area of water space, 136 acres (with 14 acres in reserve for Dock No. 10); area of land space around docks, 353½ acres, which might well be increased to 1,453½ acres by the addition of Trafford Park (or *Traffic* Park, as it is now beginning to be called), and which for many practical purposes

* The figures for Liverpool are those of Mr. A. G. Lyster, M.Inst.C.E., the Engineer-in-Chief to the Mersey Docks and Harbour Board; and the Bristol figures are those of Mr. W. W. Squire, M.Inst.C.E., the Engineer-in-Chief to the Bristol Dock Committee.

is within the dock area, though not within the area of the Canal Company's estate; length of quay frontage, 6⅔ miles; depth of water on sills of entrance locks, 28ft. These are the 1905 particulars. In 1855, and indeed in 1885, the area was partially occupied by the Manchester Racecourse and other places of concourse for persons of sporting proclivities, and partially unoccupied, except by a few lonely and melancholy cattle, a few self-satisfied and thriving hens, and, on occasions, by more than a few adventurous and marauding boys, while Trafford Park—no "Traffic," in the nomenclature then lay enclosed in its ring fence, an anachronistic and selfish survival of feudal England, a dead weight upon the skirts of aspiring Manchester, a block in the way of Manchester development, a name of unknown mystery to Manchester men.

Manchester occupies at the present time a unique position amongst the ports of the world in that it presents the *first* example of the *second* stage of an engineering development which has taken place in response to the imperative demand for cheaper conveyance of imports, such as raw materials and food products, and of exports, such as manufactured goods and minerals; the demand having in turn arisen through the great change in economic conditions which came to pass in the half century under review, and under which foreign nations, at one time such good customers of the British manufacturer; came to be his enterprising and vigilant competitors.

In order to meet the demand, it became necessary to effect a severance between the harbour space and the dock accommodation, which in the olden times were joined together in what seemed to be indissoluble wedlock. The harbour space must be on the coast-line, and there originally the dock accommodation was provided, as so long as manufacturers could obtain almost any prices they chose to ask for their goods, cost of conveyance from dock to mill and from mill to dock was of

comparatively small importance. But when prices had to be cut owing to fierce and strenuous competition, and when even with cut rates, the trade was found to be declining in the inland districts, the demand for cheaper carriage to which reference has just been made, led to the obvious suggestion that while it was inevitable that the harbour should remain on the coast it was possible and desirable to provide the dock accommodation where the works and mills were situated, and where the population to be fed had its domicile and place of occupation.

The port of Glasgow presents an admirable example of the first stage in this development, as in the words of the late Mr. Deas (formerly engineer-in-chief to the Clyde navigation) published in 1876, "the Clyde of the present day is, for a length of 12 miles below Glasgow, nearly as much an artificial navigation as the Suez Canal," that is to say, the Clyde is a typical case in which the construction of a great dock system far inland, was rendered possible by the artificial deepening of a natural water course to an extent sufficient to enable a stream once so shallow that boys could wade across it, to be navigated by great ocean steamers. Further, the Clyde not only presents an example of the severance between harbour and dock, but furnishes a somewhat remarkable example of the success of the policy of severance, when the almost unbounded success of the port of Glasgow is contrasted with the all but total failure of the port of Greenock, situated on the same river, and lying 23 miles nearer to the sea, but 23 miles farther from the centre of industry and of population.

From the enterprise which created the inland port of Glasgow by the regulation and deepening of an ineffective stream, to the enterprise which created the inland port of Manchester by the formation of an entirely artificial waterway is but one step, and the two taken together will serve to illustrate the stages in the way of dividing the harbour from the dock, and thus of pro-

viding the cheapest possible carriage for large cargoes and for goods in bulk.

Turning now to the consideration of the matter of equipment which is required for a modern dock system of a character such as that which has been described in this paper, the first observation which arises from any general view of the subject is that the complexity and inter-dependence of human life already referred to herein, finds practical expression in the working and consequently in the equipment of such a dock system.

The dock itself is first and foremost a place for the safe and sure accommodation of large vessels, to and from which they may be readily navigated, and in which they may be comfortably berthed and moored. So far the matter is one of broad and well-defined lines, and is fairly simple. But the dock system is also a centre of collection and distribution of goods and commodities of almost infinite variety, gathered from and forwarded to well-nigh all parts of the earth, civilised and uncivilised, far and near.

There are few ports in which the conditions are more complex than in Manchester; it is claimed that there are none in which the equipment is more up-to-date. A brief description of the business which is now being carried on in the port of Manchester, and of the appliances and methods by which the trade is worked will perhaps serve to give a general idea of the stage which has been reached in the evolution of the equipment of docks wherein the modern cargo steamer is berthed and at which cargoes are discharged and loaded.

For the present purpose goods may be classified in diverse manners. They may be divided into outdoor and indoor classes —*i.e.*, those which may be landed, stacked, and even stored without protection from the weather, and those for which protection and shelter are imperatively required at all seasons, together with a third class of an intermediate sort for which

partial shelter is required, but which may be allowed to remain in the open for the time being without risk of injury.

A second order of classification, less obvious than the first, but having a very important bearing upon design in dock works arises out of differences in consignment. When a vessel reaches her berth in the dock the consignees of the cargo may be in possession of information respecting one part of such cargo, but may be entirely ignorant of the ultimate disposal of another part, and may therefore be unable to furnish the dock authorities with forwarding orders for that part of the cargo or to advise these authorities whether the further conveyance thereof shall be by road, by rail, or by barge canal.

The practical distinction in the working of these two classes of cargo is that the first class, usually the smaller of the two, can be forwarded directly from the ship's side, while the second, and greater part, must be deposited either on the quay, if of the open-air quality, or in a transit shed if of such quality as to require protection.

Classifications other than the foregoing might be described, but space forbids, and these may suffice to indicate the nature of some of the problems to be solved in the provision of the equipment of a modern dock.

One of the determinative questions in dock design, which should in turn be governed by the character of the equipment required for the dock, is the proportion of land to water, *i.e.* of the area of quay space, road and railway space, storage space, etc., compared with the area of space required for the movement and berthage of vessels.

Too often the problem resolves itself into one of "cutting the coat according to the cloth," but has, owing to the demand for maximum quay frontage combined with maximum land area, generally resulted in the abandonment of the simple quadrangular form which characterised the docks of half-a-century

ago, and in the adoption of comparatively long and narrow basins with dividing piers of considerable width.

As may be expected, the proportions vary at different ports, the following table of present proportions of ratios of land and water at certain leading ports, shews this:—

LONDON	$2\frac{5}{8}$ to 1
LIVERPOOL	2 „ 1
BRISTOL	5 „ 1
MANCHESTER	$2\frac{5}{8}$ „ 1
TYNE DOCK...	$6\frac{1}{8}$ „ 1
BARRY	$9\frac{1}{2}$ „ 1
HULL JOINT	12 „ 1
GRANGEMOUTH	$13\frac{1}{2}$ „ 1

The first essential in dock working and therefore the first requirement in dock equipment is rapid despatch in the discharging and loading of vessels. The second is ample facility for the distribution of goods of all sorts over a wide area.

For rapid handling of cargo such as is required for steamers of which the daily charges run from £80 to £100, it has been found necessary in all the home ports to supplement the ship's gear by efficient cranes, and such cranes have been provided for all modern docks on this side of the Atlantic, while in sharp contrast to British practice it may be observed that it is doubtful whether there is a single crane engaged in the working of traffic of this sort on the Atlantic seaboard of North America.

At the Manchester Docks 171 cranes in all are in use for traffic purposes, or an average of one crane for every 70 yards of quay frontage.

The detailed particulars of the cranes are as follows:—

CRANES.

Power.	No. Stationary	No. Movable	Working Load.	Radius.	Maker.
Steam		1	30 tons		Stothert & Pitt.
		2	10 ,,	16ft.	J. H. Wilson & Co., Ltd.
		5	7 ,,	20ft.	Do.
		1	6 ,,	20ft.	Do.
		1	5½ ,,	20ft.	Thos. Smith.
		2	5 ,,	16ft.	Do,
		1	3 ,,	40ft.	J. H. Wilson & Co., Ltd.
		14	3 ,,	25ft.	Do.
		2	2½ ,,	14ft.	Thos. Smith.
		2	2¼ ,,	30ft.	Pearson & Knowles Coal & Iron Co. Ltd.
		4	1½ ,,	30ft.	Thos. Smith.
		11	1½ ,,	18ft.	J. H. Wilson & Co., Ltd.
		11	1 ,,	24ft.	Thos. Smith.
		57			
Hydraulic		10	1½ ,,	33ft.	Armstrong, Mitchell & Co., Ltd.
		10	1½ ,,	33ft.	Nasmyth, Wilson & Co., Ltd.
		10	1½ ,,	33ft.	Tannett, Walker & Co.
		6	1½ ,,	33ft.	Galloways Ltd.
		4	1¼ ,,	33ft.	C. & A. Musker.
		4	1¼ ,,	33ft.	Glenfield Co., Ltd.
		8	1¼ ,,	33ft.	Nasmyth, Wilson & Co., Ltd.
		52			
Electric		4	1½ ,,	20ft.	Wimshurst, Hollick & Co., Ltd.
	10		1½ ,,	12ft.	Cowans, Sheldon & Co., Ltd.
		26	1½ ,,	34ft.	Higginbottom & Mannock.
		12	1½ ,,	46ft.	Geo. Russell & Co., Ltd.
	3		1½ ,,	16ft.	Do.
	7		½ ,,	16ft.	Do.
	20	42			

Eight electric three-motor overhead travelling cranes.
Working load 1¼ tons. Span 95 feet.
Longitudinal travel 290 feet. Cross traverse 87 feet.
Makers: F. H. Royce & Co., Ltd.

The moveable cranes in the foregoing table are, with the single exception of the 30 ton crane (of which the movement is transverse) built so as to travel upon a crane road laid at the ordinary gauge of 4ft. 8½in., the outer rail of the crane road being but 5ft. 7in. from the edge of the quay.

The cranes are, in their design and in the position from which they are operated, an example of the manner in which classification of cargo affects design and equipment in dock works, as both design and position were governed by the necessity for providing for direct loading *ex*-ship into trucks or lurries of the part of the cargo of which the destination is known when the vessel arrives at the berth.

To enable this part of the cargo to be worked by the cranes, the quay space for the deposit of open-air goods and the transit sheds for goods which require protection are set back to a distance of 37ft. from the edge of the quay.

The area between the quay wall and the shed is occupied, in addition to the crane road already described, by two lines of railway laid level with the paving in such manner that either railway or road traffic may be worked over the area.

In order to assist in the marshalling of trucks and generally to facilitate the working of the rail-borne traffic on the limited space available, capstans are put down and are used with considerable advantage.

Fifty-eight capstans in all are in operation at the Manchester Docks. They are of the type employed in goods station yards, and the particulars relating thereto are shown in the following table :—

CAPSTANS.

Power.	No.	Working Load.	Remarks.
Hydraulic	17	2 tons	Tannett, Walker & Co.
	13	1 ton	W. H. Bailey & Co., Ltd.
	30		
Electric	8	2 tons	Clarke, Chapman & Co. Ltd.
	16	,,	Cowans, Sheldon & Co., Ltd.
	2	1 ton	Crompton & Co., Ltd.
	2	,,	Wimshurst, Hollick & Co. Ld.
	28		

It is of high importance, both from the point of view of the capacity of the dock for traffic, and from that of the convenient and economical unloading of the ship, that a steamer when once moored in the berth, should not be moved therefrom until the discharge of her general cargo has been completed.

In order to avoid the necessity for moving the ship, it is obvious that shed accommodation sufficient to store the whole of the general class of cargo in a length of shed not greater than the length of the vessel must be provided.

Experience has shown that for the due and proper working of cargo vessels engaged in the North American trade, 4,800 square yards of transit shed floor space should be provided for every 100 lineal feet of dock wall.*

The area required may be provided in two ways. By erecting sheds of enormous width or by building them of several floors.

The objections inherent to the first method are, that a great area of valuable land is absorbed by the wide sheds, and that the width of the sheds renders it necessary to truck goods for long distances from the ship's side, so that although much prejudice formerly existed against the multiple-floor type of transit shed, practically all recent sheds have been built of that type.

The sheds at the docks in Manchester vary too greatly to admit of extended description in this paper. Manifold methods of construction have been adopted and many types employed, so that at present there are sheds in use with one floor, two floors, three floors, four floors (including the flat roof which is available for storage), and five floors.

* The necessity for so great a shed area will become more apparent if consideration is given to the fact that in the case of American cotton, 200 different marks are frequently found in a consignment of 10,000 bales, while in the Australian wool trade the diversity of quality is even greater. Every bale of cotton or of wool must be trucked to its particular mark in the shed.

The extent of the shed accommodation now required may be gathered from the fact that the whole floor area of the various transit sheds on the dock system, as distinguished from the storage warehouses, is over 66 acres.

The maximum possible use of the portion of the dock system set aside for traffic which requires shed accommodation is gauged, not by the rate at which cargo may be deposited in the shed *ex*-ship, but by the rate at which the cargo may be cleared *ex*-shed into lurry, railway truck or canal barge; as at the best the clearance of the cargo from the shed occupies twice the time required for the discharge of the cargo from the ship.

It is therefore obligatory that the sheds should be fitted with appliances by which goods deposited therein may be loaded out with all possible speed.

Nearly all transit sheds which have more than one floor are now fitted with loading-out gear of the ordinary simple barrel and brake type, but this equipment was soon found to be insufficient for the rate of working required at the Manchester Docks, and these appliances were supplemented, first by hydraulic jiggers with a stroke of 100ft. and a lifting capacity of 30cwt., of which 30 are now at work; at a later date by electric cranes erected on the roof at the back of the sheds (of which 10 are now in use); and still more recently by electric cranes at the ends and electric hoists (with a traverse of 8ft. 6in. and a capacity of 30cwt.) at the back of each shed. At the ferro-concrete sheds on the southerly side of the new dock (No. 9), 10 roof cranes, and 25 hoists have been fitted.

So far, in dealing with the classes of goods which require protection from the weather and therefore which must have transit shed accommodation until ultimately their destination is ascertained, the case of cargo of the general class only has been considered. But it is, even in the provision of transit shed accommodation, becoming now-a-days more and more necessary

to specialize, to provide specially equipped shed sections and to set these sections apart for particular commodities which demand special treatment. Commodities of a perishable nature furnish a case in point.

Year by year the importation into Great Britain of beef, mutton and lamb, of cheese, butter, eggs, fruit, etc., is increasing, as the difficulty of feeding so great an industrial population as that which is packed into this very partially agricultural island increases. These food stuffs are drawn from an area which is already wide, from Canada and from the United States, from New Zealand and Australia, from the Argentine Republic, etc., and which will grow wider and still more wide.

The development in the trade has been remarkably rapid. In 1875 the first attempts to convey meat from America to England in chilled rooms were made with but indifferent success. By the year 1879 it may be said that success in trans-atlantic conveyance had been achieved, while in 1880, meat was for the first time shipped in Australian ports and delivered in good condition in the British markets. For the over sea conveyance of these perishable commodities, special provision is now made in all the large steamers engaged in the trade between this country and the territories just named, these vessels being fitted with refrigerated holds in which temperatures are maintained of 18° Fah. for frozen goods, 28° Fah. for chilled meat, 36° Fah. for butter, etc., and so on.

When the frozen or chilled goods are landed, they are conveyed with the least possible delay to permanent cold storage depots, such as those erected by the Manchester Corporation in Elm Street in this city, and by the Colonial Consignment and Distributing Company on the north bank of the Ship Canal in Weaste in the Borough of Salford.

But such conveyance takes time, and in order to avoid delay to the steamer, it has in some cases become necessary to provide

in the shed at the steamer's berth, cold space in which the artificially frozen goods may be deposited *in transitu*, and in which they may be sorted and may be preserved from the effects of a rise of temperature. The requirements imply that the cold space shall be effectively insulated and that the temperature therein shall be maintained at the particular point demanded, by means of suitable refrigerating machinery, a complication in shed design little dreamed of, even a few years ago.

In addition to the dead meat in their refrigerated holds, certain lines of steamers carry live stock on their decks. Under the rules of the Board of Agriculture, formulated in order to prevent the introduction of disease by these "foreign animals," cattle or sheep so conveyed must be slaughtered at the place at which they are landed.

Dock owners have been compelled to meet the difficult conditions brought about by these regulations by the erection of great establishments which occupy large areas of land and which comprise lairages, slaughter-houses, chill-rooms, etc. The lairages provided, by the beneficent enterprise of the Manchester Corporation, on the south bank of the canal at Mode Wheel, furnish one of the finest examples of these establishments to be found in this or in any other land. The site occupied is 12 acres in extent, accommodation has been provided for 1,800 head of cattle at a cost of £90,000, and meat is now being distributed from the chill-rooms not only throughout England, but is even being sent to Germany *via* Grimsby.

Grain, in all its varieties, is another class of cargo which calls for special treatment, not so much because of special character, but because of great bulk and because it is imperative that the people shall have cheap bread, and therefore imperative that the grain shall be handled at an almost infinitesimal cost.

Grain, like the other food stuffs to which reference has been made comes to this country from many parts of the earth. From some parts, such as India, Russia, the Western States of America, the River Plate, etc., the grain is conveyed in whole cargoes; from others, such as Canada, the Eastern States of America, etc., it furnishes only part of the cargo of a steamer which may with the grain bring cotton, timber and general cargo.

The grain elevator system, so fully developed in North America, furnishes the most ready, rapid and economical method for handling grain in bulk, which human ingenuity has yet devised; and for dealing with whole cargoes cannot be equalled by any existing method of operation; as a steamer conveying grain exclusively can be berthed at the elevator and can have the entire cargo lifted, weighed, graded and passed into store in a minimum of time at a minimum of cost. This system has been in very successful operation at the Manchester Docks since the year 1898, and in respect thereof no further observation need be made here as some description of the plant and of the methods by which grain is handled therein has already been given to the Association.

The part cargo problem in grain conveyance is more difficult. The grain is naturally stored as low down in the holds of the vessel as is possible, and in many cases the most convenient course, even though additional time is required and the movement of the vessel is involved, is when the other parts of the cargo have been cleared, to berth the vessel at the elevator for the discharge of the grain. In other cases when despatch is of the first importance, and when the parcels of grain are small, these parcels are worked out of the ship's holds by means of floating elevators, moored on the off-side of the steamer, and deposited in barges which are afterwards conveyed to the main elevator; where the grain is again lifted and in which it is eventually stored.

In dock No. 9 of the Manchester system (the dock which was opened by H.M. the King last year) special arrangements have been made for dealing with grain in parcels and part cargoes. Briefly, the arrangements are as follows. At the easterly end of the dock, foundations have been formed upon which it is intended that a second grain elevator with a capacity similar to that of the elevator at Trafford wharf (40,000 tons) shall be erected. The elevator having been designed especially for dealing with parcels of grain will, instead of one main marine leg, have on the side facing the quay, six different legs for elevating grain; so that six different classes of grain may be received, weighed, and distributed at one time. For the conveyance of grain to this elevator house, special subways have been constructed in the dock walls. These subways will in each case be fitted with four sets of conveyor belts formed in lengths of 450ft. each, and will extend throughout the whole distance covered by the subways. Each belt in each length will be driven by an independent motor of 30 BHP, and the whole will form a system by which grain imported as part of the cargo of any vessel berthed in the dock, will be lifted from the holds by means of moveable elevators of the crane type, passed through small hatches in the quay on to the several belts, and carried by the belts directly to the respective lifting legs in the elevator house.

Facilities for clearing goods from transit sheds, however admirable and however effective, are useless if not supplemented by equally effective facilities for the conveyance of the goods from and to the sheds; in other words, in any dock system the question of transportation of goods of all sorts from the dock and to the dock is one of paramount importance.

In some ports (Manchester and Liverpool are among them) the transportation question is rendered more complex by the fact that three different methods of transportation are in

operation—*i.e.*, by road on lurries, horse drawn or motor propelled; by water in canal barges; and by rail on trucks. While the further fact that at Manchester the rail borne part of the transported merchandise is regularly carried in the trucks of no less than seven different companies* may serve to indicate the extent of the railway accommodation required.

During the period in which traffic has been worked on the Ship Canal, railway formation has proceeded continuously at the Manchester Docks, so that at the present time the lengths of the various running roads and sidings in operation amount in all to 61 miles. There is not in the whole system a dock or basin, a quay, a shed, or a storage warehouse which has not a railway line on each side of it. In fact, the docks as a whole may be regarded as a huge waterside terminal goods station, and thus form a centre of collection both actual and potential, to which it is difficult to find a parallel.

Thirty-eight locomotive engines are now employed exclusively in the working of the dock railways, for which the requisite addenda in the form of running sheds, water columns, coaling stages, etc., have naturally had to be supplied.

Year by year the number of engines has increased and is increasing, and at the same time the weight and power of the locomotives have also gone far beyond those originally contemplated. The heaviest engine in present use weighs 44½ tons when coaled, and has cylinders 18ins. × 26ins,, while the most general type has a weight of 32½ tons with cylinders 15½ins. × 20ins.

If a detailed description of the dock equipment which has been evolved by the exigencies of the shipping trade of the present day were carried to the bitter end, the inordinate length

* The companies are, first the Canal Company, which now owns a large number of railway trucks, and secondly, the owners of what are known as the "foreign" trucks—viz., the L. & N. W., L. & Y., G. N., Midland, G. C., and C. L. C. Railway Companies.

of the description would render it impossible to persuade present-day impatience either to read the description or to hear it read. Nothing has been said in this paper as to the special requirements of special trades, such, for instance, as the trade in tropical fruits, bananas, etc., which has become such an important part of the imports into Manchester; nor has anything been said as to the provision which must always be available for supplying steamers with fresh water; nor as to the lighting of the dock quays, roads, and railways; nor as to the highly organised system of fire protection which is now necessary on every dock estate; nor as to the many other matters which might be of interest, and certainly are of importance in the working of dock traffic; but probably the description which has been given of a part of the equipment of the Manchester Docks will be sufficient to demonstrate the entire accuracy of the proposition that the complex conditions of modern life are reflected and find expression in the equipment of a modern dock.

DISCUSSION.

Mr. Thomas Ashbury said he thought Mr. Hunter was correct in stating that the time had arrived when the Association was bound to look at and take some interest in the harbour and dock equipment of the Port of Manchester. It was not many years back when Manchester was isolated altogether from the sea, and only a few years still further back when Liverpool was a rising port. He remembered his first going to Liverpool as a boy on a steamer from Runcorn, that the passengers had to climb a "Jacobs" ladder from the steamer to the pierhead, as there was no landing stage, and not one quarter of the docks existing there as at the present time.

Manchester had developed in a very unique form, and its docks ought to be supported, as they could be with advantage. The illustration which had been given in the Paper, of Greenock and Glasgow, was very forcible, and ought to encourage Manchester people that the right thing had been done in placing the docks here, in the centre of the trade of the district.

He felt a little proud when Mr. Hunter referred to the iron and steel ships, when he remembered that one of the Association's own members, the late Sir William Fairbairn, was one of the pioneers in the construction and development of the iron shipbuilding industry for oversea traffic.

In regard to the dock accommodation of Manchester and its equipment, he had seen many docks elsewhere, and remembered many years ago being depressed when walking along the docks at Hamburg, and seeing the magnificent arrangements made there in dock equipment compared with the miserable dock equipment in the prominent Port of Liverpool. He was gratified to think that Manchester now stood second to no port in the world in regard to dock equipment. About a year ago a Glasgow friend of his was holding up the Port of Glasgow as an ideal place which no other could beat in regard to its docks. One day he came to Manchester and was taken to see the Ship Canal and its equipment, when he was greatly astonished at the rapidity with which an ocean going vessel's cargo could be discharged, and at the admirable arrangements for the separating of the cargo into different classes, before delivery into railway wagons or into the warehouse, and to see the despatch with which a cargo after being unloaded into the warehouse was so soon on its way to its destination, either by lurry or railway.

Manchester was now profiting and would no doubt continue to profit for generations from the works resultant from Mr. Hunter's skill and forethought.

A great compliment had recently been paid to the City of Manchester, by the President of the United States of America, and that compliment was especially in honour of Mr. Hunter, the engineer-in-chief of the Manchester Ship Canal, and by reflection from him to the Manchester Association of Engineers, in this way. After the years of difficulty and disappointment which had existed since the Panama Canal was first initiated, and also since its being turned over by the French to the United States Government, it was a wise thing when it was suggested that there should be an international consulting engineering expert commission to consider and advise on the best scheme to ensure success. The President of the U.S.A. Government applied to the British Government to select an English representative, and they recommended Mr. Hunter as being one of the best men in this country to give the advice required. He, Mr. Ashbury, was very pleased to know that Mr. Hunter's suggestions to the Commission were very likely to be carried out in their entirety; and when it was remembered that the canal would represent under the modified conditions an expenditure of about 28 million pounds sterling, he thought the U.S.A. Government would have reason to appreciate the wisdom, and to thank the U.S.A. President in calling outside assistance and council.

Although Manchester went so boldly ahead in the development of its Ship Canal, it seemed to him that they did not go far enough in their sanguine expectations, and that if Mr. Hunter had to design the canal to-day, and had a free hand, he would provide still greater facilities for present and future trade.

He tendered his congratulations to Mr. Hunter for his excellent paper, which was so full of valuable information of a special character.

It was worthy of the fullest confidence, as being the result of Mr. Hunter's unique and great experience. He wished to

express his personal thanks to him for closing the year of the Association's Jubilee Session, with a Paper, which for years to come, would be looked upon as the high water mark in connection with that particular subject, and would interest and connect the Association with oversea-going traffic, harbours, docks and dock equipments.

Mr. A. V. Coster said he wished to thank Mr Hunter for his able paper, which to him was one of especial interest. He had seen some of the docks in the East, China, India and the Mediterranean, and could only wish that when he was at sea there had been the facilities in those docks that Manchester now possessed for the rapid discharge of cargo.

One of the improvements that Mr. Hunter had initiated in the Manchester docks, was the utilisation of the Crossley internal combustion engine. He hoped this experiment had been a success. These engines, driving hydraulic pumps, were used for hoisting coal wagons on to elevators for the rapid discharge of coal into ships' holds and bunkers. In Liverpool recently he saw coal being discharged into the hold by means of baskets, which seemed a very antiquated method, and he wondered that Liverpool should be so far behind the times in this matter, whereas in Manchester the contents of coal trucks, about five to eight tons at a time, could be emptied bodily into the holds. He was aware that the hand basket was used only for passenger steamers to prevent injury from coal dust, but he felt sure a better method was in vogue at Manchester.

Another development of interest in connection with docks was also the use of gas engines in conjunction with centrifugal pumps for emptying graving docks. The Mersey Dock Board had two new docks fitted in this manner, and could be emptied in three hours from the opening of the starting valve. That seemed to him a very great advance, as there were no boilers to

be kept with banked fires, and the plant required less attention and the saving of fuel, even when working on town's gas, amounted to over 50%. It was evident that the fact of our enormous waste of coal was being more largely recognised, and influential engineers such as Mr. Hunter were determined to risk a great deal in order to reduce it.

He hoped other ports would follow the lead of Manchester and Liverpool, and also that in due time the necessity for baskets or hydraulic hoists would be greatly modified when internal combustion engines were found on shipboard, and vessels then would be able to travel three times the distance with the same coal bunkers.

Mr. E. P. Hetherington remarked in respect to the limits of the size of locks, that during the early stages of the Manchester Ship canal construction, he strongly urged that wider locks should be made at the entrance to the canal, and the same width continued along the canal with the idea that there should be facilities for British battleships to come up the canal 20 or 30 miles, beyond the range of an enemy's guns, to, say, an inland arsenal, whereby guns and other equipment could be put on board without the interference of the enemy.

With respect to the quay walls of the Manchester new dock, he did not wish to depreciate Mr. Hunter's design, but had an idea there was something similar in use in other dock walls; he had certainly seen the archways similar to the Manchester ones, but without the slope. He believed he had seen them at Glasgow, but could not say whether Manchester had copied the design from Glasgow, or Glasgow from Manchester. The same thing was also done in a somewhat similar way on sea wall frontages, to prevent the wash of the waves on to the promenades.

He understood that the five acres which were taken up by the discharged and ingoing cargo, was due to the warehouse accommodation being equal to the five or six decks of the steamer, but was spread out in the various floors, and that the ingoing cargo would be berthed next to the steamer, and the cargo discharged from the vessel would be put to the far side to facilitate its transhipment on to the lurries or railway.

About 10 years ago he was rather disappointed that more use of the coal trade was not made on the Manchester Ship Canal, but was then informed that it was such a low paying rate, 6d. a ton, that it did not pay. This class of trade, however, was now being worked.

In respect to Mr. Coster's remarks as to the coaling of ships at Liverpool by baskets, that occurred on a passenger boat only, and the reason the coal was put into the holds in that manner was to prevent the dust destroying the embellishments of the vessel.

Mr. Matthew Ingram stated he was pleased to give his testimony to the admirable manner in which the paper had been presented, and whilst admitting, as all admitted, the magnificent service that the Ship Canal had done to the County of Lancashire, and the City of Manchester, he trusted that through the instrumentality and genius of Mr. Hunter the question of inland navigation would be tackled so that much larger benefits would be derived from it. The home trade of the future would be of the greatest interest to the Engineers of England, and especially of Manchester; and this would be fostered and promoted by inland navigation.

Too much had not been said of what Engineers had done for the progress of this Country, and of the World in general. Engineers had revolutionised the industrial methods of mankind by the introduction of the steam engine and the

steamship, the one having covered the land by a perfect network of railways connected to countless factories, and the other encircled the seas, bringing to us the produce of other lands for the advantage and welfare of mankind.

As the Ship Canal has been to the advantage of the City of Manchester, so would the extension and improvements of the inland canals add prosperity to the rest of this country by cheapening cost of transit, and thereby production, and thus fostering the promotion of home or village industries where employment may be obtained for the villagers where they can enjoy a healthy life instead of crowding into the towns and cities, where their conditions and environments do not conduce to either a healthy or useful life.

Mr. Alfred Saxon said that the paper was a most interesting one, and showed Mr. Hunter's complete mastery of the subject. It would be agreed that in the case of Manchester, at any rate, the divorcing of the harbour from the dock was justifiable.

Although the Americans often claimed they were ahead of England, when he was at Pittsburg a short time ago, sailing on the river, he saw the appliances they had in connection with the locks, and called the attention of some Americans to the fact that our Ship Canal Lock appliances were a long way ahead of theirs.

Mr. William Ingham remarked that the paper was not one which lent itself to animated discussion, such as some papers did which had been read, and the discussion could only be of a very general character. Mr. Hunter had given particulars of the remarkable development in the sizes of vessels; and this reminded him of some lectures by Professor Osborne Reynolds at the Owens College some years ago, in which he pointed out that the only structure, to the size of which there was no limit,

was a floating vessel. Bridges, girders, etc., could be enlarged until they would break by their own weight. There was a limit to the size of steam engines and steam boilers, and in fact to all structures except floating vessels. There was no limit to the size of these, because the greater they were made the greater was the amount of water displaced, and the consequent "power of flotation" which sustained them. Therefore, notwithstanding the huge vessels which were now built, and, as Mr. Hunter pointed out, which were still to be built, there was absolutely no limit in the direction of size and bulk, and this gave rise to interesting considerations as to the size and design of docks to be provided in the future.

Mr. Robert Matthews in proposing a hearty vote of thanks to Mr. Hunter for his paper mentioned that it had been a most valuable contribution to the Annals of the Association.

Mr. W. Henry Hunter in acknowledging the vote of thanks, thanked the members for the courteous and appreciative manner in which they had listened to the paper.

GAS, OIL AND PETROL ENGINES.

READ SATURDAY, MARCH 10TH, 1906,

BY

Mr. HENRY N. BICKERTON,

ASHTON-UNDER-LYNE.

There are few subjects which have been recently reviewed, that have received more attention than that relating to gas engines. I suppose the chief reason for this is, that during the last ten years, great advance has been made in connection with them, and this, coupled with their undoubted economy in fuel consumption, has increased the possibilities of their advantageous application.

Recent progress has been so rapid, that it is tempting to speculate on what still remains to be done, and to indicate important future improvements which may not unreasonably be expected. But such is not the object of this paper, which is rather to lay before you a summarised account of the history of the subject with some reference to present practice.

The historical character of this paper has been suggested, in view of the present jubilee session of this Association; and when we recollect that there are more gas engines made in this immediate neighbourhood, than anywhere else in the world, this particular side of the matter has its interest.

HISTORICAL ACCOUNT.

There were undoubtedly many early attempts to produce power by the ignition of combustible powder in an enclosed vessel, but I do not propose to go further back than the close

of the 18th century, when John Barber obtained a patent for a heat engine in the year 1791, in which after producing the gases in a heated retort they were to be pumped with a proportion of air into the exploder. After ignition they issued from a restricted mouthpiece in a continuous flame against the vanes of a paddle-wheel; water was introduced into the mouthpiece, which being turned into steam assisted the general action. The construction somewhat resembles the recently proposed gas turbines.

Three years later, in 1794, Robert Street obtained a patent for an engine foreshadowing important features in the modern engine. A cylinder and piston were employed in his construction, spirits of turpentine or petroleum were injected into the cylinder which was heated externally by a fire to vapourise them. After air had been sucked into the cylinder by the upstroke of the piston, an external flame was drawn into the cylinder also, to ignite the mixture, the explosion being used to force the piston through the remainder of its path, and also the piston of a pump for the purpose of raising water. It will thus be seen that in Street's engine we have the admission of air by suction, the internal vaporisation of oil and ignition from an external flame.

In the first year of the nineteenth century a French engineer, Phillippe Lebon, made an important step in the practical application of gas engines. The inflammable gas, with sufficient air to make it ignite, were introduced separately into the cylinder on both sides of the piston, and the inventor proposed to fire the mixture by an electric spark; the machine was double-acting, and the explosion of gas took place alternately on each side of the piston; two pumps were used in which gas and air were compressed before they entered the motor cylinder, these pumps, together with the machine for generating the electric spark, were driven from the motor shaft. It is thus

clear that Lebon realised the importance of compression before ignition, and also the difficulties of ignition under compression, and it is a matter of great regret that his work was cut short by his assassination in 1804.

Samuel Brown, about 1826, constructed what was probably the first gas engine to work in London on the atmospheric principle, the combustion of the air and gas being used for the purpose of forming a vacuum, but it was not until 1838 that any advantage appears to have been taken of Lebon's suggestion of compression.

In this year William Barnett took out a patent, No. 7615, which I consider is justly looked upon as one of considerable importance, as it contained novel and interesting features, and anticipated in many ways modern gas motors. Barnett describes three types of engines and a flame ignition arrangement. In the two first engines the air and gas were compressed separately into a receiver, and allowed to enter under the piston of the engine at about 25lbs. pressure, being ignited as they entered. It is in the third engine that Barnett comes so near modern practice; in this engine the air and gas are compressed in separate cylinders, the receiver being abolished. The working piston had an exhaust port about midway in its path through which the exhaust gases were discharged; after the piston passed this port the air and gas were admitted into the cylinder from the pumps, in a compressed state, and, being further compressed by the backward motion of the piston, were ignited at high compression on the dead centre and expanded during the full path of the piston.

The flame-igniting arrangement described by Barnett consisted of a large gas-cock with a small internal flame burning in the plug; this internal flame was lit by an external flame as the cock revolved, and the general action was very similar to the slide valve flame ignition so largely used by Messrs.

Crossley Bros. on the gas engines of twenty years ago. Considering that Barnett's engine had compression before ignition, ignition at the dead centre, full expansion during the whole forward stroke, and that there was also present in the cylinder that charge of incombustible gas which was the bone of contention in the subsequent litigation on gas engines, we may feel somewhat surprised that Barnett's engine did not attain more success; but the mechanical construction was bad, and the manufacture of inflammable gas had not attained that degree of perfection that was necessary to make a gas engine compete favourably with the steam engine.

In 1843, there was exhibited, at the Philadelphia Exhibition, an interesting engine constructed by Dr. Drake. It was of a horizontal type, and ordinary lighting gas, with nine or ten times its volume of atmospheric air, were drawn into the cylinder by the piston, being afterwards ignited by a small incandescent tube, heated by an external flame; this engine also worked with petroleum vapour. It belongs to the type of non-compression explosion engines, and is worthy of note as having used an incandescent tube for ignition purposes.

We now come to a long pause in connection with the development of the internal-combustion engine. For twenty years nothing of real merit appears to have been constructed or suggested, and it would seem that during the first years of the existence of this Association the gas engine problem was lying dormant.

No doubt considerable thought was being exercised, for as we now know M. Beau de Rochas in the year 1862 filed a patent specification in France which formulates a complete theory of the cycle of operation which ought to be carried out in a gas engine to utilise more completely the heat supplied. The suggestions contained in this patent are embodied in almost all

modern gas engines, as the following extract from the specification will show.

"The question of heat utilisation being thus stated, the only really practical arrangement is to use a single cylinder, first that the volume may be as large as possible, and next to reduce the resistance of the gas to a minimum. The following operations must then take place on one side of the cylinder, during one period of four consecutive strokes:—

1. Drawing in the charge during one whole stroke.
2. Compression during the following stroke.
3. Inflammation at the dead point, and expansion during the third stroke.
4. Discharge of the burnt gases from the cylinder during the fourth and last stroke."

We have here described the very cycle of operations almost universally used in all gas engines of the present day. The only thing wanting in Beau de Rochas' proposal was a more satisfactory method of ignition. He suggests that the ignition should be effected as a result of compression, but whilst this is quite possible, it has not been found very practical.

For fourteen years, these important proposals lay unadopted, and there is little doubt that few engineers knew of their existence, or if so, realised their far-reaching importance, for it was not until 1876 that Dr. Otto applied them successfully in the construction of his renowned silent gas engine.

During the period of 1862—1876, many attempts were made, some with considerable success, to produce gas engines of small powers generally as explosive engines without compression acting direct on the crank, such as the Bisschop which many of you will remember as a very useful little engine, an importation from France where it was exhibited at the Paris Exhibition of 1878. A large number of these engines were made at Stockport by Messrs. J. E. H. Andrews & Co., who by their strict

attention to detail, high finish of cylinder and piston, got them to work freely without lubrication, oil not being permissible due to the high temperature. They were, however, confined to very small powers, their gas consumption was high, about 85ft. per BHP, and were rather noisy in working.

The most notable engine, however, during this period was Messrs. Otto & Langen's atmospheric engine in which the piston was allowed to move freely in a long vertical cylinder, and having been forced up by the explosion of air and gas it descended, partly by its own weight, but principally due to the atmospheric pressure, a partial vacuum being formed in the cylinder,—as a result of the cooling and condensation of the exploded charge. During its descent the piston rod, which was formed as a rack, engaged with the flywheel shaft transmitting its power into rotary motion.

Although this engine worked economically it was, like the Bisschop engine, limited to very small powers; the mechanical detail difficulties were never completely overcome. Nevertheless, Messrs. Crossley Bros., after greatly improving its construction, made some thousands of them, and it is probably to this engine (which was often termed "The Jumper") that most of us owe our introduction to the gas engine. It came as a boon to those requiring small power at a short notice, and it did something more useful still—it showed by its ready sale the necessity for something better. This necessity, which is so often quoted "The Mother of Invention," together with the fact that coal gas had been so universally adopted throughout the country for lighting purposes, and was therefore easily obtainable for power, caused a number of inventive minds of the day to turn their attention to the construction of gas engines.

One of the most notable of these was Mr. Dugald Clerk, of Glasgow, who in 1880 exhibited a gas engine as a result of several years experimenting, and working on different lines to

that of Beau de Rochas' or Otto's cycle. In the Clerk engine a working impulse was obtained on every forward motion of the piston, whilst its back motion was used only for the purpose of compression.

The displacement of the burnt gases, and the substitution of them in the cylinder with a new charge, was performed by the aid of an auxiliary cylinder and piston called the "Displacer," which made its stroke during the period that the crank of the main piston was passing the dead centre, and the exhaust ports, which were placed at the outer end of the cylinder, were uncovered by the piston. The "displacer" cylinder was sufficiently large, and the charge in it so arranged, that the main cylinder was first swept by air only, which was afterwards displaced by the explosive charge. Thus the burnt gases of one explosion were removed from, and the new charge placed in the cylinder, ready to receive the compression on every back stroke of the piston.

This cycle admits of many modifications, and a number of gas engines were made by different makers adopting the cycle of Mr. Clerk in one form or another, the most notable being the Stockport engine as made by Messrs. J. E. H. Andrew & Co., of Reddish, who continued to manufacture engines on this cycle until 1890, when the lapse of the Otto patent permitted the general adoption of the Otto cycle, together with a number of important improvements adapted by them. It is interesting to here note that this cycle of Mr. Clerk's has recently been adopted by several makers of large gas engines on the Continent and their English licensees.

I must also mention in connection with this period, the name of Mr. Atkinson, one of our members, who so early as 1879 patented a compression engine in which ignition was obtained by the use of the heated tube, and is one of the first instances of such an engine firing the gas in this way. Mr. Atkinson's

subsequent efforts were devoted to producing a gas engine in which the whole of the burnt gases were displaced before the new charge was introduced, and the ignited charge expanded beyond its original volume. A study of the Atkinson engine of 1884 and 1886, in which this object was accomplished, is conclusive evidence of Mr. Atkinson's great ability when dealing with mechanical difficulties. The cost of production of the Atkinson differential engine prevented it competing with the simpler Otto cycle engine, and therefore its adoption was limited; at the same time its practical and economical working were thoroughly demonstrated in the Society of Arts trials in 1888, where an Atkinson engine of about 10 HP gave a heat efficiency of 19 %, whilst a Crossley engine of larger size gave a heat efficiency of 18 %, and the Griffin engine of 17 %.

With the filing of the patent No. 2081, 1876, by Nicolaus August Otto, the era of gas engines really begins, for although Beau de Rochas was the first to formulate the programme of what was necessary, to Otto we must accord the credit of being the first to carry out that programme in a satisfactory and practical manner, and the Otto engine, which was first exhibited at Paris in 1878, was the father of the gas engine of to-day. It is unnecessary for me to describe this engine, or to go into its cycle of operations; they are practically as described by Beau de Rochas. The great and important feature in connection with it was undoubtedly the compression before ignition, and yet it is curious to notice what little stress is laid on this fact in Otto's specification, its silent and economical working is attributed to another element, viz., the presence in the cylinder of the incombustible material consisting of the products of the previous combustion left in the combustion chamber, and so not swept by the piston, together with air drawn in previous to the explosive charge, and so located in the cylinder as to form a cushion between the explosive gases and the piston. A great

deal of time and money were spent for the purpose of proving the correctness, or otherwise, of this theory, as upon it the validity of the Otto patent in this country depended, with the result that at the important trials before the Law Courts, which form one of the most notable features in the history of the gas engine, this theory, as set forth in the Otto patent, was maintained.

Thus it followed that Messrs. Crossley Bros., as the sole licensees in this country of Dr. Otto, held the market, and manufactured the great majority of engines which were used in this country up to 1890, Now although this localised the gas engine industry to this neighbourhood, it is reasonable to suggest that had it been possible for other firms to have been engaged in the manufacture of gas engines on the Otto cycle, at this time, there would have been more minds at work on the subject, and as a natural consequence development would have been accelerated.

It is a matter for consideration whether some alteration in our patent laws could not be made to advantage. The inventor, on the granting of a patent, should have more protection, but at the same time, to my mind, this protection should be one which, while calculating to ensure his receiving a fair remuneration in the way of Royalties (where his invention is employed) should not create a monopoly.

That the original Otto engine had many defects was apparent to all who had any experience of them, but they were an advance on what had been previously attempted, and commanded a ready sale.

The ignition arrangement which consisted of a slide valve and travelling flame, although much improved by Messrs. Crossley Bros., was still the cause of endless trouble. It was extremely expensive in the use of oil, and further stood in the way of increased speed of rotation and increased compression

before ignition, thereby keeping down the working economy of the engine.

I think I am right in saying that the first important improvement in connection with the Otto engine was the adaptation of hot tube ignition. As I have pointed out, this method of ignition had been suggested by Dr. Drake in 1843, and had been applied to a compression engine by Mr. Atkinson in 1878, but was, I believe, first shewn in a practical form as applied to a gas engine on the Otto cycle made by a Bradford firm and exhibited at a Bradford Exhibition in 1882.

The patentee, Mr. William Watson, in his specification No. 1723, 1881, describes the construction of a hot tube ignition device for gas engines in which a space beyond the heated part is formed to receive (due to compression) the incombustible gases left in the heated part of the tube, and thereby allow the combustible gases to come in contact with the heated part, and thus ignite. It is needless to say that all hot tube ignition arrangements are constructed on these lines, although, of course, the details of Watson's arrangement have been considerably improved. The metal tubes described by him have been discarded for porcelain tubes, which are practically indestructible, and the timing valve, for regulating the moment of ignition, has been perfected both by Messrs. Crossley Bros. and other makers.

With the improved method of ignition by hot tube and timing valve, the historical part of this paper may be concluded.

PRESENT PRACTICE IN MODERATE SIZE GAS ENGINES.

In referring to gas engines of moderate size I include units which will develop from 50BHP to 100BHP on producer gas.

Engines of 50BHP are very extensively used for ordinary workshop purposes in this country, and I therefore propose to

describe such an engine with reference to the essential conditions which at the present time govern its design.

The engine works on the Otto cycle, is single acting, and has three main valves, namely, the gas valve, main inlet valve, and exhaust valve. The main dimensions are as follows:—Cylinder diameter 14in., stroke 22in., speed 160 revs. p.m. When firing every cycle such an engine may be expected to develop 58IHP and 50BHP on producer gas.

The following are the chief points in construction:

(*a*) *Crankshaft*. This should be amply strong with good bearings. There has been a tendency in the past to make the crankshafts of gas engines rather lighter than experience has shown to be desirable. There is not the slightest doubt that in the majority of cases where gas engine shafts have broken, the failure has been due simply to weakness and to no other cause. This point is now well understood, and in the best modern engines there is little risk of failure on this account. Better methods of lubricating the crankshaft bearings are now being devised, and my own firm with, I believe, others of the best makers are now introducing automatic ring oilers for these bearings.

(*b*) *Connecting-rod*. The connecting-rod itself is usually made of mild steel, and the brasses at each end are preferably of the marine type, so as to afford ready means of adjustment. It is now well understood that though the ordinary Otto gas engine is single acting, and that therefore there is no direct stress on the connecting-rod bolts due to the explosion, these bolts should be made amply strong to resist the very considerable inertia forces. These bolts may with advantage be made of treble best wrought iron with fine screw threads.

(*c*) *Piston*. It is of advantage that the length of this should not be restricted, and there should be a good bearing surface on the piston body quite apart from the length in which the

piston rings are placed. The position of the piston pin should be such that the thrust pressure is as far away from the rings as possible.

Careful attention should be given to the design of the piston so as to secure an equal amount of expansion in all directions.

Regarding the lubrication of the cylinder and cross head pin, many continental makers fit a small force pump in order to force the oil into the cylinder. This, however, is quite unnecessary as with a little care in detail it can be arranged for the oil to flow in quite readily by gravity.

(*d*) *Cylinder and Liner.* The cylinder casing itself is usually arranged to include the main inlet and exhaust valves. In the engine under consideration the exhaust valve only is arranged in the casing, the admission valve being bolted on the back of the latter in a separate casting. The cylinder lining is of hard cast iron accurately bored, and it is essential that all parts exposed to heat should be free from blow holes or flaws. The liner is held in place by bolts passing through the casing which maintains the liner joint at the back end. The front end of the liner is a sliding expansion joint. The space between the liner and cylinder casing forms, of course, the water jacket.

(*e*) *Valves.* All valves should be of ample area, so that the flow of gaseous fluid, both in and out of the cylinder, is as little restricted as possible. This is specially necessary where suction producer gas is used in order that a reasonable mean pressure in the cylinder may be obtained. It will be seen that any choking of the inlet flow results in a greatly diminished weight of charge being present in the cylinder at the end of the suction stroke, hence the whole range of pressure is lower than it otherwise need be.

(*f*) *Governing.* In the type of engine described nothing better has yet been devised than the ordinary hit and miss

governor. It is simple in action, effective in its results, and may be relied upon to work with certainty with very little intelligent care or attention. The method usually adopted is to directly control the gas inlet valve from the governor, which selects whether the gas valve be opened or not.

(*g*) *Ignition.* Where the engine is working on town's gas the ordinary tube ignition with timing valve is quite satisfactory in its action. The great majority of engines of this size, however, are required to work with suction producer gas, in which cases electric ignition is invariably fitted, and as there are extremely few published descriptions of such electric ignition gears as are most commonly adopted, a detailed reference to the same will not be out of place in the present paper.

(*h*) *Electric Ignition.* It has become almost a standard practice with all makers to use a magneto in conjunction with a mechanical "make and break" within the cylinder in order to produce a low tension spark for igniting the mixture. The mechanical "make and break" is arranged in a removable plug fitted to the cylinder in such a way that the striking lever operating the armature of magneto also produces the breaking movement of the contacts within the cylinder at the right time. The armature of the magneto should be set so as to produce the maximum potential at this moment.

The electric ignition gear for such an engine as that under consideration would consist of a cast iron plug passing through from the exterior of the cylinder casing to the interior of the combustion chamber. It makes a pressure joint on the coned seating near the latter. In the plug are two spindles, one firmly fixed, and prevented from making a metallic contact with the plugs by insulators. The other spindle is free to oscillate and carries on its inner end a striking lever which ordinarily rests on the projection of the insulated spindle. There is also a tappet lever fixed on the outer end of the

moving spindle, which is struck, every time a spark is made, by a hardened pin on a lever attached to the armature spindle, and which in turn is operated by a striking peg or cam working on the main cam shaft of the engine. The movement of the tappet on the outer end of the moving spindle in the plug causes the lever at the inner end of the same to break its contact with the insulated spindle within the cylinder, and as the armature of the magneto is set so as to give the maximum E.M.F. at this moment, a good spark is produced.

It will be obvious, of course, that one terminal of the magneto must be earthed through the engine while the other is connected by insulated wire to the insulated spindle on the ignition plug. The magneto itself is simply a small dynamo with permanent field magnets, and an H type armature with simple windings. Springs are fitted to the moving spindle on the plug and to the operating lever of the magneto in order to effect the necessary return movements of the mechanism.

(*i*) *Starting Arrangements.*—Small engines up to 30HP. can be started with sufficient facility by giving a few turns by hand in the first instance, using the flywheels for the purpose. But above this size a self-starting device is necessary. In the engine under consideration a small hand pump is used for pumping an initial charge into the cylinder, the suction valve of which is made with a double seating respectively controlling the air and gas supply, so that during the suction stroke of the pump they are drawn in a proper proportion to give an explosive mixture.

There are two delivery valves, and a connection is made from the discharge branch of the pump to the cylinder, a screw-down valve being provided at the latter so that the pump and its connection can easily be shut off. As a matter of fact, the screw-down valve referred to is only opened while the starting charge is being pumped in, and is shut immediately afterwards,

The two delivery valves are thought desirable where tube ignition is employed, so as to obviate any chance of a considerable pressure being communicated to the pump chamber in the event of a premature ignition during the pumping operation. There is, however, little likelihood of this happening under ordinary circumstances, and with electric ignition the chances are nil.

The operation of starting is as follows :—

The engine is barred round until the crank is about 40° above the centre on the power stroke of the engine: all valves are accordingly shut. The exhaust valve is propped open, and the screw down connection from pump to cylinder is also opened. A number of strokes of the pump is then made, and an explosive mixture enters the cylinder and displaces the inert air, or products therein through the exhaust valve. The latter is then closed and a further number of strokes of the pump is made, with the result that a slight compression is obtained in the cylinder.

The mixture is then fired by hand, either from the hot tube or by the electric ignition as the case may be, and a good and silent impulse is obtained sufficient to carry the engine round four or five times. When the next power stroke has been reached the piston has automatically drawn in a charge which is fired in the usual way, and the cycle of operations continues until the normal speed of rotation is reached.

I have found the foregoing arrangement to work satisfactorily in engines up to 300 BHP, where it has been possible to take off all external resistance, so that the engine starts against its own friction only.

No doubt in large engines a compressed air arrangement is better, but as this necessitates a large air receiver, and an auxiliary small engine, and compressor for charging the same, it is only permissible in large installations.

In connection with starting devices generally, I would like to mention that the first successful arrangement of importance was that invented by Messrs. Clerk and Lanchester, and subsequently adopted by Messrs. Crossley Bros. The chief difference between this invention and that which I have just described in detail, lies in the addition of an external receiver of about three times the volume of the engine cylinder which was used in conjunction with the latter, both receiver and cylinder being filled with mixture for the purpose of starting. This comparatively large volume was necessary as ignition could only take place at atmospheric pressure, and though the detail arrangements are very ingenious, and reflect great credit on the inventors, later methods such as I have described are simpler and more effective.

(*k*) *Thermal Efficiency.* With reference to some remarks I have to make later on the subject of large engines, I would here like to draw attention to the high thermal efficiency obtainable with such an engine as that just described. I quote from the report of a committee of the Institution of Civil Engineers appointed on the 6th November, 1903, under the chairmanship of Professor W. C. Unwin, F.R.S., to consider and report to the Council on the Standards of Efficiency of Internal-Combustion Engines.

Three "National" engines were placed at the disposal of the committee, types "L," "R" and "X, the latter being the size I have just described. They develop at full load 5·17, 25·9 and 56·3 EHP, with a gas consumption of 16·87, 15·84 and 14·90 cubic feet per BHP hour, thus showing a thermal efficiency reckoned on BHP of 26·1, 28·0 and 29·9 respectively. The gas used during the foregoing tests was Ashton gas of an average lower heating value of 585 B.T.U.'s.

I am also able to give you the results of a test of a "W." type "Stockport" gas engine of 160 BHP working on town's gas

at Messrs. J. L. Thompson & Sons Limited, Sunderland, the gas consumption at full load being 14·4 cub. ft. per BHP hour with gas of a net calorific value of 562 B.T.U's. A comparison between the gas consumption given for the 50 HP National and the 160HP Stockport engines are specially interesting, as they show that the gain in thermal efficiency as the size of the engine increases is practically negligible above 50 HP, and I would ask you to specially note this fact.

The general economy of engines of smaller powers than 50HP is very striking, and to illustrate this point I cannot do better than to refer you to the published results of the Glasgow trials held in July, 1905, by the Highland and Agricultural Society of Scotland, when the declared coal consumption for the 10BHP and 20BHP "National" engines working with suction plants was ·84 and ·80lbs. respectively of Scotch anthracite per BHP per hour at full load, and ·87 and ·86lbs. respectively per BHP hour at half load. I do not think that better results than these would be expected in the ordinary way from engines of 300 to 400 BHP or larger, and, in the official report on the test, attention is drawn to the fact that the results mean that with these small gas engine units *20 BHP* can be developed continuously over one hour for the sum of *one penny.*

Generally the moderate sized gas engine, for which after all there is the greatest demand, has been brought to a high degree of thermal and mechanical perfection. It has made it possible for the small user to obtain his power at the cheapest rate. Public supplies, whether of gas or electricity, need no longer be considered as the necessities for industrial localities, for the gas engine in its modern form can provide power and light, if need be, at a cheaper rate than such sources can possibly give it. This important consideration will undoubtedly have a far reaching effect in the future.

LARGE GAS ENGINES.

So far as this country is concerned, units of from 250BHP to 500BHP would be usually considered large engines, though in the last two years there have been a small number of engines of about 700BHP constructed.

I need not tell you that on the Continent engines of from 1,000BHP to 2,000BHP are not uncommon, and we read accounts of larger sizes even than these. Like many of you, I have personally inspected such engines, and it will be agreed that they reflect great credit on those responsible for their construction. Though they embody no novel principles so far as their respective cycles of operation are concerned, they certainly do comprise a wealth of carefully devised mechanical detail in their construction. As a whole they work well and represent a great development in gas engine practice, and several important English firms not hitherto connected with the gas engine trade have now arranged to purchase the knowledge of their friends abroad and to build engines in this country after the continental patterns.

I attribute these foreign developments to three chief reasons: firstly, the Otto patents were not upheld in any other country than our own; hence prior to 1890 gas engine construction was not confined to one firm. Secondly, the last decade has witnessed the inception of many new and important iron works in Germany, and it is in such establishments that large units can be most advantageously employed. In our own country where the iron trade has long been a going concern, the old plant can only be gradually replaced. Thirdly, as a result of the peculiar economic conditions obtaining in Germany, the gas engine users have been compelled to accept responsibility for a large part of the loss arising from the failure of vital parts of large engines during the experimental period, which in this country would fall entirely on the engine maker.

There are, however, in addition, the following important considerations, which, so far as we are concerned, undoubtedly have a direct bearing on this matter, and are well worthy of attention as referring to present practice in this country:—

(*a*) The thermal efficiency of large units is not higher than with small units.

(*b*) The cost per horse-power of an aggregate of smaller units is not greater than the cost per horse-power of the same power in one unit.

(*c*) The space occupied by a number of smaller units is not sensibly greater than if the same power in large units be adopted.

(*d*) The risk of failure of vital parts in large engines is undoubtedly much greater than with small sizes.

(*e*) Large engines undoubtedly require higher skill on the part of the attendant, and general administrative anxiety and responsibility are greatly increased.

(*f*) A number of units give a much greater elasticity of working and factor of reliability.

With regard to the first point (*a*) above, I have already shown you what thermal efficiences can be obtained with small engines and these are not surpassed by the largest engines.

Taking the above considerations as a whole it will be seen that they constitute a very strong argument for having in any given case a number of small units preferably to one very large unit, and, speaking from my own experience, it is the exception rather than the rule when the former are not permissible.

This is specially the case where the engines are to be used for generating electricity, for, as the dynamos can be run in parallel, I consider it more advantageous to combine the energy to a required total in the electrical mains from a number of units of fair size rather than to have one or two big sets. The external result is the same, while, so far as the engines are

concerned, there are the very great advantages I have just indicated.

For such reasons as those just given I am of opinion that until some great advance is made which will enable gas engine makers to overcome the troublesome temperature difficulties experienced with large engines by simpler means than those at present adopted, a group of smaller units will be applied wherever possible for obtaining large powers. That this condition is transitional I readily admit, and, as you are no doubt aware, my colleague, Mr. Dugald Clerk, is at the present time devoting a great deal of attention to the methods whereby a reduction of flame temperature within the cylinder can be conveniently secured. I think there is no doubt that future development will tend in this direction, for the present alternative of obviating heat troubles by elaborate cooling water arrangements is obviously a crude method which must sooner or later give place to more scientific means.

Full descriptions of large Continental gas engines have recently appeared in the technical journals, and most valuable and fully detailed information relating to them was also given in M. Rudolphe Mathot's paper read before the Institution of Mechanical Engineers at Liége last year (1905).

I would also like to refer you to Mr. Humphrey's important contribution to the British Association in 1902.

In view of this up-to-date and easily available information on Continental practice, I feel that I may be excused from again traversing what has already been done so well.

One of the first, if not the first, large gas engines made in this country was a 400BHP tandem cylinder Otto cycle "Stockport" engine with two 25½ins. diameter cylinders by 36ins. stroke using Dowson pressure gas. Our member, Mr. A. R. Bellamy, was responsible for the design of this engine, which was supplied in 1893 and worked with creditable success. His

firm (Messrs. J. E. H. Andrew & Co. Limited) have continued since then to make units up to the size mentioned above.

Messrs. Crossley Bros. have maintained their position in the front rank of English makers. The largest engines they have working in this country are those recently supplied to the Mersey Docks and Harbour Board for driving centrifugal pumps. Two of these engines, which are each of 500BHP, working with town's gas, were started at the beginning of the year and are, I am informed, doing well. This firm also recently supplied four engines each of 580BHP to Mexico for driving alternators in parallel, and they have given satisfaction.

My own firm (the National Gas Engine Company Limited) have recently supplied an installation of 1,500BHP to the Castner-Kellner Alkali Company Limited, Runcorn, consisting of six units of 250BHP each, working on Mond gas. The engines drive dynamos in parallel and work continuously night and day at full load for electrolytic work. This plant has given entire satisfaction. We have a great many similar engines in hand at the present time of from 150 to 350BHP. Up to 150BHP, single cylinder single-acting engines are adopted, and from 200 to 350BHP we fit twin side-by-side cylinder engines with double throw cranks. I am glad to say that we have been so successful with this latter class that we have now no hesitation in offering engines of 600BHP. These latter will have four cylinders with four throw cranks giving a perfectly balanced engine.

None of these "National" engines to which I have referred have water-cooled pistons or exhaust valves, but only the usual water circulation through the cylinder jackets, and while using high compression there is a complete absence of pre-ignitions. We have engines of the sizes named working on Mond gas, water gas, blast furnace gas, coke oven gas, in addition to ordinary producer gas. We regularly guarantee our large

engines and gas producers to work continuously over 144 hours (one working week, night and day) without stoppage of any kind.

About three years ago Messrs. Mather & Platt Limited, of Salford Iron Works, Manchester, took up a license for building two cycle gas engines of the Koerting type. They have installed two such engines of 700BHP each at the Castner-Kellner Works, and they have in addition built five or six others.

The Westinghouse Company are identified with vertical gas engines, and they have built and installed a fair number of these. I have not been able to obtain any detail information in respect of them, but I believe in many instances they are working well.

The Premier Company, of Nottingham, claim to have more engines at work on Mond gas and blast furnace gas than any other make. The special feature of this engine is the scavenging arrangement, consisting of an auxiliary air pump which drives a charge of air through the compression space in the working cylinder after the exhaust valve opens, thereby cooling the combustion chamber and driving out any lurking flame which might prematurely ignite the next incoming charge. Premier engines are made up to 2,500HP.

Messrs. Beardmore and Co., Glasgow, are building Ochaelhauser engines of 400BHP upwards. A full description of these engines has recently appeared in "Engineering."

Messrs. Richardson, Westgarth & Co., Middlesbrough, have taken up the "Cockerill" engine, and have now some important installations of large engines at work in the recently remodelled iron works on the North East Coast.

I will not be expected to make comparisons between the respective merits of the various types of engines to which brief

reference has just been made, but in concluding this section of the paper I may perhaps be permitted to say that with large gas engines the usually recognised value of simplicity as a means to success has been shown by experience to be all-important.

OIL AND PETROL ENGINES.

As pointed out in the historical part of this paper, the suggestion to use petroleum in the internal combustion engine is quite as old as that to use gas, but it was not until about the year 1878 that an engine of anything like a useful character was produced. Brayton, an American engineer, who had some years previously placed upon the market a petroleum motor, exhibited at the Paris Exhibition in 1878 a single-acting engine of the vertical type working on the principle of combustion at constant pressure, petroleum being forced through a gauze screen by compressed air into the cylinder and ignited; the increased volume forced forward the piston. Mr. Dugald Clerk, in 1878, made a test at Glasgow on a 5HP American Brayton petroleum engine, which ran at a speed of 200 revolutions per minute, but too much power was absorbed in driving the air and petroleum pumps, and the heavy consumption of oil (being 2·16lbs. per IHP per hour) prevented the engine from making much progress.

The first oil engine of note was made by Messrs. Priestman, who, in 1888, constructed an engine on the Otto cycle. The petroleum used was blown into a vapouriser by compressed air through a nozzle called "the sprayer"; the vapouriser was kept at a considerable temperature by the exhaust from the engine; the combustible charge was drawn into the cylinder from the vapouriser, and the ignition of the charge was accomplished by an electric spark. A considerable number of these engines were manufactured, but the electric ignition used in those days was very defective, so that although the oil consumption was only ·94lbs. per BHP hour, as shown by Professor Unwin's test

in 1891, the Priestman engine had to give place to the simpler form of oil engine, viz. the Hornsby-Akroyd.

The great success of the Hornsby-Akroyd oil engine, patented in 1891, can be attributed to two leading features,—the absence of any igniting device, such as electric ignition or hot tube, and the absence of any external flame, so that although the oil consumption was probably a little higher than in engines constructed on different lines, its simplicity in management, and its reliability, made it a useful motor for agricultural purposes, and it is therefore not surprising that at the Royal Show tests made at Cambridge in 1894, it received the highest award.

I remember that this award caused considerable dissatisfaction at the time, as there were other engines that worked more economically, but taking into account the fact that Messrs. Hornsby have since supplied the majority of oil engines for agricultural purposes, the gentlemen who were responsible for the award showed great soundness of judgment.

The practicability of a motive power engine using petroleum having been established by Messrs. Priestman, brought many makers into the field, all of them using the Otto cycle of operations, but differing considerably in the manner in which the oil was converted into gas, and the manner in which the charge was ignited in the cylinder. Putting aside the Diesel engine, about which I will speak later, they may be divided into three classes. 1st. Engines in which the oil is vapourised and ignited by the internal heat generated from the working of the engine itself. 2nd. Engines in which the oil is vapourised separately from the engine, wholly or partially, by means of heat supplied from an independent source. 3rd. Engines in which the oil is vapourised internally, partially by means of the heat supplied by the previous combustion with added heat from an independent source.

The Hornsby-Ackroyd engine, as made by Messrs. Hornsbys, of Grantham, was practically the only engine of Class 1, its special construction consists of the formation at the back of the cylinder of a vapouriser or explosion chamber connected to the cylinder with a restricted passage, and permanently in communication with it. The valves for the admission of air, and the outlet of the exhaust open into the cylinder proper, but the oil-feed is through a fine nozzle into the vapouriser. After having raised the temperature of the vapouriser by the application of heat from a temporary lamp, sufficiently high to not only vapourise the oil internally but to ignite it when under compression, the engine is ready to start, and will continue to work without the assistance of any added heat, and therefore all external flame is dispensed with. It is no doubt true that the point of ignition in this engine under varying loads is somewhat precarious, and also that the mean pressure obtainable is comparatively low, necessitating a large engine for the power developed, still its compensating advantages have made it the most popular oil engine.

The Crossley oil engine, as made until very recently, may be taken as a typical illustration of Class 2, the oil being drawn by the suction of the engine, together with some air, through a vapouriser whose communication with the cylinder is controlled by a valve. The vapouriser in this engine obtained its necessary heat principally from a lamp, the flame of which heated also the ignition tube for the purpose of igniting the charge in the cylinder, the moment of ignition being controlled, as in a gas engine, by a timing valve. There were undoubtedly some advantages in an engine of this kind when worked in a proper manner, as the charge is better mixed than in engines of Class 1, and higher compressions are obtainable because the charge is enclosed in a water-jacketed compression chamber and cylinder, and therefore is not liable to ignite until the

required moment. The better mixing of the charge and the higher compression not only reduced the size of the engine for a given power, but also increased its economy in oil consumption.

There are many makers of engines as described in Class 3, Messrs. Tangyes, Campbell, Cundall and others. The oil in these engines is taken into the cylinder through the admission valve along with the air charge, and is arranged to be broken up by it into fine particles. The admission valve opens into the vapouriser, which is in communication, by a passage, to the cylinder. This vapouriser retains considerable heat from the previous explosion of the engine, but not sufficient to ignite the charge without the additional help of an external flame; a tube with one end permanently open to the vapouriser is sometimes fitted, and assists in the ignition, being placed in such a position as to receive the principle heat of the lamp.

An interesting petroleum engine is now made by Messrs. Gardiner, of Patricroft, who I understand are making a large number of high speed oil engines for marine and similar purposes, somewhat on the lines of those which I have placed under the heading of Class 2, but with the improvement that they have taken advantage of recent developments in electric ignition and applied the low tension magneto with an internal "make and brake" arrangement, as already described in this paper in connection with gas engines.

The Diesel oil engine in its mechanical construction and cycle of operations is very like that of all other internal combustion engines, but it differs from them all in the fact that it is not an explosive, as we generally understand the term, but a combustion engine. The maximum temperature having been reached, due to the compression of the air in the cylinder by the back stroke of the piston, compressions of about 30 atmospheres being used, the oil is injected in a finely divided manner

by compressed air from a receiver at about 40 atmospheres. The oil is consumed as it enters, and the heat generated is carried off by the expansion of the gases. Apart from the mechanical difficulties, and specially high-class workmanship necessary when dealing with compressions like 30 to 40 atmospheres, it will be apparent that an engine of this kind admitting the use of crude petroleum with a high flash point must have many advantages over the oil engines as before described, but I would refer any of our members who are anxious for more information with respect to this engine to Mr. Michael Longridge's report for 1904, in which a very full and interesting account is given of a test made on a three-cylinder inverted vertical Diesel oil engine of about 500HP, the oil consumption working out at ·451lbs. per BHP of Galacia oil, costing £4 per ton delivered at the works.

Looking at oil engines generally, I am inclined to think that their day is passing; the introduction of the suction plant, which carries with it most of the advantages which the oil engine possesses, together with the fact that it will work more economically than the best of them, leads me to this conclusion.

I come now to the petrol engines, which are closely allied, as a class, with oil engines, and which, due chiefly to the motor-car industry, have become very generally familiar. It is impossible to attempt to describe the different types of motor-car engines with their varied forms of electric ignition, their automatic or mechanically moved admission valves, their different systems of governing, different styles of carburetters, and so forth. This branch would more fitly form the subject of an independent paper.

The general problem of the petrol engine is a comparatively simple one, for we have given a substance which will vapourise at atmospheric pressure and temperature, and so can be drawn into the cylinder as a gas. Such vapourisers or carburetters as

are necessary may be of the simplest forms, and as the ignition is always effected by electrical means, the two chief difficulties met with in the ordinary oil engine are immediately disposed of, and the petrol engine becomes more like an ordinary gas engine, in its general cleanliness and certainty of working.

For small powers—say up to 5BHP,—petrol engines may be advantageously employed for ordinary industrial and domestic purposes where town gas is not available, and for the powers mentioned they are generally preferred to the ordinary oil engine.

PRODUCER GAS.

The marked success of the small gas engine when using town's gas, and its proved economy as a heat motor, demonstrated that it was only necessary to produce a cheap gas, to make it rival the steam engine of large powers as an economical motor, just as it had rivalled the steam engine of small powers as a motor of convenience.

Sir William Siemens, so early as 1861, had made satisfactory gas for manufacturing purposes by the combustion of coal in a producer, and a working apparatus for the production of water gas had been invented by Donovan in 1830; but the Siemens' gas was not sufficiently rich to drive gas engines, and the production of water gas was precarious in its procees. What was necessary was a simple method for the manufacture of power gas, and Mr. J. E. Dowson was the first to produce this, by admitting superheated steam and air through a furnace together, which was proposed by him and patented in England in 1879.

The Dowson gas plant consists of a steam boiler with superheater attached, an injector, through which a current of air is forced by the velocity of the issuing steam under the grate of a producer, thence through the incandescent fuel, and on through the scrubbers into the gas holder. The producer in a plant of

this kind is generally cylindrical in form with a good lining of fire brick, and the fuel used must be either gas coke or anthracite coal: all attempts to use bituminous coal in such plants have been unsuccessful until very recently. The manufacture of Dowson power gas from anthracite coal or coke is simple and highly satisfactory: thousands of HP are being driven daily, and for a long number of years Mr. Dowson held the field without serious rivals.

The gas produced broadly contains the characteristics of Siemens' gas and water gas; it has a very large percentage of nitrogen and carbon mon-oxide, and the following may be considered as a fair sample of its analysis:—N 58·6, CO 27·6, H 7·0, CO_2 4·8, CH_4 2·0. The heating value is about 145B.T.U. per cubic foot, and the amount of fuel required per HP in a good installation would work out at ·75 of Welsh anthracite coal, and 1·125 of good gas coke per BHP hour, a cost in fuel equal to about half of that required for a high-class steam engine.

There were many makers of power gas plants very much on the same lines as Mr. Dowson's, and differing only in detail of construction, until about the year 1893, when Leon Benier, of Paris, constructed a plant for the manufacture of this gas in an automatic manner exactly in proportion to the requirements of the engine to which it was attached. This simplified the process considerably. In the first place the gas holder was dispensed with, and, what was more important still, the necessity for a steam boiler separately fired was avoided, thus leaving only the generator and the scrubbers.

The great feature of the Benier plant was the employment of the suction of the engine to draw the necessary air and steam through the generator which Dowson, in his plant, forced through by the pressure of the steam from the boiler. To Benier we must accord the credit of being the first to produce

that suction gas plant which is at the present time taking such a prominent position in this country.

Although many public tests were made by eminent men with satisfactory results, and although the use of the suction plant made considerable headway on the Continent, it was not until something like ten years after Benier's first plant was made that English manufacturers turned their attention to it, Dr. Bowman, of the Dynamic Gas Co., being one of the first. Messrs. Dowson having all the special knowledge necessary for the manufacture of gas plants together with the facilities at their works, have placed on the market suction gas plants of all sizes, from 10 to 300 BHP, so that already there are several hundreds of their suction gas plants with National gas engines successfully at work in this country with a highly economical fuel consumption, as shown by the Glasgow tests already referred to.

Besides the adoption of suction plant there have been two other important developments in connection with gas engines and cheap gas, probably the most notable being that of utilisation of high furnace gases which are drawn from the top of the furnaces, and after being passed through scrubbers, to take out the dust and other impurities, are supplied to the engines. Many large installations of this kind are very successfully at work on the Continent, and to a growing extent in this country, the power developed being utilised for the purpose of running the air blowers to the furnaces from which they obtained their gas.

These installations are the result of successful experiments commenced at the beginning of 1895, by Mr. Thwaite, with an Acme gas engine of about 30 HP, at the Wishaw Iron Works, near Glasgow, and by the Society Cockerill at the Seraing Works, in Belgium, where a Simplex engine of 8 HP, of French manufacture, was employed. So satisfactory were the results

of the tests made that the latter have installed a number of large gas engines of their own manufacture, and many thousands of HP are being generated not only for blowing purposes but for electrical energy, and are driving almost the whole of the machinery in their vast works.

The high furnace gas is somewhat similar in its character to the Dowson gas; it is, however, of a much lower heat value, varying from about 100 to 110 B.T.U.'s per cubic foot. In some instances the necessary cleaning before its use becomes difficult, as it varies considerably in its character in accordance with the ore used and the fuel employed.

A development of more importance to this country, and one which has made more headway than the utilisation of high furnace gases, is the manufacture of power gas from bituminous coal or common slack. The first plant of this kind was erected by Messrs. Brunner, Mond & Co., at Northwich, gas being used from it for power purposes for the first time in 1894, when a 100HP engine was put to work for generating electricity.

The valuable feature of the Mond plant is the recovery of the bye-products and as much as 90lbs. of sulphite of ammonia can be obtained from a ton of fuel used, together with upwards of 150,000 cubic feet of gas of a heat value of 150 B.T.U.'s per cubic foot. For large gas plants with proper recovery of the bye-products, the Mond appears up to the present to have no rivals, but for moderate sizes, which are really of more interest to the gas engine manufacturer, there are several makers.

One of the first to come into practical use is a development of the Wilson gas producer, which for a number of years has been used for industrial purposes. In its recent development, as made by the Horsehay Co. Ltd., the gas is sufficiently cleaned from tar and other impnrities as to make it suitable for use in gas engines. There is no attempt on the part of the Horsehay plant for the recovery of anything but the tar in its simplest

form, but as this tar is recovered without an objectionable amount of water, it is of considerable value. The principle feature claimed by the makers is that a very small amount of water is required to clean the gas, which is stated to be not more than two-fifths of a gallon per BHP, a fact which appears to me to be of considerable importance, as any local difficulty in dealing with the effluents is consequently minimised.

The principle of reducing the gases to a low temperature by means of contact with a cool surface and thus depositing the tar before it is finally treated with water would appear to be highly satisfactory, and the results obtainable from the Horsehay plant, from a fuel consumption point of view, compare favourably with the best yet obtained, as shown by the following particulars of a test extending over twelve months.

COST FOR ONE YEAR'S WORKING OF A 250 BHP GAS PLANT.

	£	s.	d.
Coal, 486 tons at 6/3	151	17	6
One attendant (including overtime for cleaning)	70	3	6
Stores, sawdust, &c.	3	13	0
Interest and depreciation—10% on £875 ..	87	10	0
	£313	4	0

$$\text{Cost of gas} = \frac{£313\ \ 4\ \ 0}{486 \text{ tons}} = 12\text{s. } 10\text{d. per ton of coal burnt.}$$

Taking the output of gas as 140,000 cub. ft. per ton of coal gasified, we get :—

$$\frac{154}{140} = 1{\cdot}1\text{d. per } 1{,}000 \text{ cub. ft.}$$

And as $4\frac{1}{2}$ cub. ft. of producer gas do the same work as 1 cub. ft. of ordinary town's gas, 1·1d. × 4·5d. = cost of amount of producer gas equivalent to 1,000 cub. ft. of town's gas.

The gas plant manufactured and sold by Messrs. Crossley Bros. has been so recently and so fully dealt with by Mr. Rigby in his paper, read before you twelve months ago, that I do not

think it is necessary to do more than call your attention to it. Like the Horsehay, up to the present it has been confined to moderate sized plants with no special attempt for the recovery of the bye-products, and is particulary interesting as having an ingenious arrangement for mechanically extracting the tar from the gases by centrifugal force. I understand that the future developments of the Crossley plants will be in the direction of ammonia recovery and the construction of them in large sizes of several thousand HP each, many of which they have at present in hand.

Another type of gas producing plant from bituminous slack is the one made by Messrs. Mason & Co., of Levenshulme, and is distinctive from the others in that the tar contained in the bituminous coal is treated in the producer itself in such a manner that it is permanently fixed, thereby enriching the gas produced, and at the same time dispensing with that part of the apparatus that would be otherwise necessary to wash it out. This principle of treating the tar in a generator, which has been adopted by several gas plant makers besides Messrs. Mason, would theoretically appear to be the right one, and it will be interesting to note which of the two systems will eventually survive the other.

My thanks are due to Messrs. Crossley Bros. for the information given as to their large gas engines and gas plants, and to Mr. A. R. Bellamy for that relating to the Stockport gas engines. I am also indebted to my colleague, Mr. Philip Robson, for his assistance in the preparation of this paper, in which I have tried to put before you, so far as time has permitted, the general aspects and principal features in the development of the gas engine industry, as they appear to one who has been exclusively connected with it since 1878, and as such I hope the paper may interest that large body of our members to whom the subject is not so famiiiar.

DISCUSSION.

The PRESIDENT (Mr. Robert Matthews) in declaring the discussion open, remarked that the Paper had been most interesting. In connection with the question of governing, no doubt there was some better system than the "hit and miss," and this point would probably provide good discussion.

Mr. JAMES ATKINSON stated that Mr. Dugald Clerk had exhibited an engine before the one mentioned as having been shown in 1880. This was in 1879 at the Kilburn Show of the Royal Agricultural Society; it was not the type of engine which was afterwards known as the "Clerk" engine, but an engine with a separate pump.

With reference to firing the charge in the gas engine with the hot tube, it would be advisable to put this matter in a little more definite manner than Mr. Bickerton had mentioned. It had a most important bearing on the introduction of the gas engine. As explained in the Paper, slide ignition crippled gas engines for a great many years, and tube ignition was a very great advance on anything that had been done before. An engine had been mentioned which was made by Mr. Sam Clayton, Bradford, fired with hot tube ignition under the patents of Mr. Wm. Watson, but his own (Mr. Atkinson's) patent which described the heated tube, was taken out previously to either of Mr. Watson's patents, and as far as Mr. Watson was concerned, he was prior to him in this invention. The engine on which Mr. Atkinson put it was one of the first compression engines he made, but after it was made he came to the conclusion that it would have been an infringement of the Otto patent then in existence. The consequence was that that

engine was never exhibited, and although it was fired with the hot tube it was never publicly known as being so ignited.

Mr. Watson some years afterwards complained that the compression engines which were then being made with hot tubes infringed his patents, but on seeing Mr. Atkinson's previous patent was satisfied that it was prior to his own. He was also at the same time shown an old patent of Sir William Siemens taken out some years before, which foreshadowed a hot tube sufficiently to prevent him (Mr. Atkinson) from making a valid patent.

It would be interesting to know that on those particular engines not only were iron tubes used by him (Mr. Atkinson), but porcelain tubes also; the porcelain tubes, however, were not very satisfactory because they could not be got to stand the pressure. Ordinary chemical porcelain tubes were used, cut to lengths, but it was a very difficult matter to do, and the result was that the porcelain tubes were given up and iron tubes used.

The breakage of many gas engine crankshafts had been stated to be owing to want of strength, but his experience of such breakdowns had been that they generally occurred with shafts which had three bearings. A gas engine had to have a very heavy fly-wheel, especially if for electric lighting purposes; there was considerable difficulty in keeping the three bearings in absolute line, and if they were not in absolute line the shaft had to be deflected each revolution, causing a considerable strain which eventually broke it. The bulk of the fractured shafts he had had experience of for many years had been in engines which had three bearings; but with two-bearing engines there had been almost an absolute immunity from breakdown.

The President in his opening remarks had seemed to think something better than the hit and miss governor could be done. To a certain extent, he, (Mr. Atkinson) agreed with

the author that the hit and miss governor was as simple as it possibly could be and was good enough for the bulk of purposes, but there were many cases where it was not sufficiently good, and then something better was required. Roughly there were about four different methods of gas engine governing; one by throttling was largely used by the Westinghouse Company and by some of the Continental makers. This was very simple, and in many cases very satisfactory, but with a large engine which had considerable inertia of moving parts, and more particularly with a tandem engine with more than one piston on the one rod, a high compression was required, or a compression sufficiently high to take up the inertia of the parts, or the engine would not run smoothly. With a throttle governor there was a reduced compression at the light loads, and the consequence was that with such engines the inertia of the moving parts could not be taken up, and a knock occurred at the time of ignition; for such purposes therefore throttle governing could not be used satisfactorily. This did not apply to ordinary single cylinder engines, because the inertia of the parts of such engines was not great and it could be taken up with a very much reduced compression pressure; but where there was more than one piston on one rod, throttle governing was not sufficiently good and a type of governor must be used with which full compression pressure could always be obtained. That could be got in two ways. One was to throttle the gas and get varying richness of charges into the cylinder; this, however, was not very satisfactory because the amount of governing to be got in this manner was very limited as a charge which was either too rich or too weak in gas could not be burnt satisfactorily and economically.

The type of governor which seemed to him to promise the best success was one which had been adopted by several large

Continental makers; it was brought out by the late Mr. Frank Crossley many years ago, but was not very satisfactory at that time. This method of governing was to vary the time at which the gas was admitted during the suction stroke, but always to cut it off at the end of the stroke at the same time, and thus in the cylinder the charge was stratified. Near the piston was almost pure air when working with a light load, and at the end furthest from the piston there was a proper mixture which on compression could be fired satisfactorily and would give an economical and satisfactory diagram. The reason it was now satisfactory, and not at an earlier period, was that then the compression pressure was probably only about 45lbs. per square inch, but now it would probably be about 150lbs. or possibly more. The higher compression brought the particles of gas and air more intimately together, and gases distributed amongst an excessive amount of air had a better chance of being burnt. A further reason was that when working with compression pressures of about 150lbs. the heat due to the compression itself brought the charge up to the point at which it would nearly ignite, and a very slight excess of pressure or temperature would burn it; thus the particles of gas which were mixed up with the very large percentage of air were economically burnt, and the result was that what was an uneconomical method of governing then was now a very economical type.

Some gas engine makers had said that stratification could not occur, others who had gone more deeply into the matter had stated that there *was* stratification in gas engines. In the Korting and Oechelhauser engines working with this method of governing, this stratification occurred to a very large extent. The point had been very much discussed, and that was a conclusive proof that stratification did take place in gas engines as they were now made.

Mr. Bickerton had referred to the Clerk & Lanchester starter. This patent was bought by Crossleys many years ago, and a great number of these starters were used; it was a means by which an engine could be started with a very considerable portion of load on it, and with the belt on the tight pulley driving a considerable length of shafting. That was a very great point in connection with gas engines, because it obviated the necessity of using a fast and loose pulley or a friction clutch. It had been a very successful patent, and Crossleys still made a very considerable number of these starters.

In a recent paper by Mr. Rigby on producer gas some figures were given respecting the efficiencies of gas engines. He would like these to be compared with the figures given in the present paper.

He agreed with the author in his remarks about the efficiency of gas engines not increasing with very large engines. In this connection an engine giving about 60 or 70 to 100BHP was about as economical as any gas engine which was made. This to a large extent was due to the volume of the cylinder being such that the gas was more thoroughly burnt during the time it had to burn; with a very much greater cylinder possibly the gas would not be burnt so thoroughly. Another point why large gas engines were not likely to be more economical than smaller engines, was that very large engines were now made with a piston rod passing through the middle of the charge, and this was a most efficient condenser in the very worst place.

Respecting the cost of large and small engines, he agreed with Mr. Bickerton that beyond a certain size, large gas engines could not be made any cheaper per horse power than moderate sized engines. It was very similar with marine steam engines, although the corresponding power was much greater.

One point about using a considerable number of small units instead of one large engine, was that this better suited gas

engine makers. A considerable number of gas engines were used to drive electric machinery, the tendency being to use three-phase alternating current, and this meant practically that there should be four cylinders in each engine, thus the engine had almost of necessity to be a large one. If continuous current dynamos had only been adhered to, gas engine makers would have been much better pleased; but still the conditions of the day had to be met, and the ordinary single cylinder engine had to give place in many instances to multi-cylinder engines.

The Brayton oil engine mentioned was exhibited at the Kilburn Show at the same time the Clerk gas engine was shown. It was a most interesting engine, and it was a pity it was not further developed on the lines on which it was then working.

Dr. Bowman had been mentioned as one of the first to make suction gas plants in England. The first plant suitable for running as a suction plant, however, was made by Crossleys; it was designed by himself (Mr. Atkinson), and exhibited at the Royal Agricultural Show at Cardiff. It worked successfully throughout the Show, and was the basis on which suction plants had since been made by Crossleys.

Mr. R. Onions said he had listened to the paper with great pleasure and was very much indebted to the author for the information given; it dealt not only with the author's own experience, but the general practice in this country so far as the manufacture of gas engines was concerned.

The gas consumption of the small Bisschop engine was given at 35 cubic feet per BHP per hour but the actual consumption worked out at between 90 and 120 cubic feet. The engine however was economical in other respects in that it required

practically no lubrication or water, and occupied very little space.

A point about the Bisschop engines not generally known is that they could be started automatically, the method of self starting being exactly the same as employed in the Lanchester low pressure starter.

Dealing with the point of crankshafts, he agreed with the remarks of a previous speaker in reference to the strain likely to be brought about with three bearings; the alignment of the outer bearing was more or less a difficult matter to keep right unless every care was taken with the foundations. It is also of considerable importance that the shaft should be made as flexible as possible by having no abrupt changes in section; that is, the smaller diameters should always join the larger by means of very liberal fillets, particularly so about the crank-pin and at the point where the body of the shaft meets the cheeks.

In practice it is rarely found that the shaft fails in the body or parallel portion; it is more often in one or other of the corners, generally brought about by local strains, while a larger fillet would have distributed the deflection over a greater area.

Messrs. Andrews were the first in this country to introduce the ring oiling arrangement for bearings, the first engine being sent out in April, 1904.

Regarding the lubrication of the cylinder and crosshead pin, their experience has been somewhat different from the author's as they had found the Continental practice to be very satisfactory in this respect. There was little doubt but that the force pump for the cylinder and an independent arrangement for lubricating the crosshead pin was the best method.

When any wear took place in the liner, or when any draught was caused by passing the rings, the oil was blown away from the surface to be lubricated, and the crosshead pin for large

engines being of quite moderate proportions, if not lubricated, soon wears and creates a knock.

Electric ignition gear could not be considered altogether satisfactory unless some means were adopted so that the time of ignition could be varied whilst the engine was at work, as the time of ignition requires adjusting with varying loads, gas mixture, and speed.

Andrews formerly used the fixed point of ignition but now employ eccentric motion by which the time can be varied to a considerable extent both for starting and also whilst the engine is at work.

The air starting arrangements did not necessarily mean the adoption of a separate engine to compress the charge. It was only necessary to have an air container which could be charged from the engine cylinder itself. The "W" type mentioned in the Paper had a container 2ft. diameter by 4ft. long, and this can be charged with air up to within about 10lbs. of the compression pressure after the time the gas has been shut off and the engine is coming to rest, by having a bye-pass non-return valve to allow the compressed air to enter the vessel. With suitable valves there is no difficulty in retaining this compressed air for long periods.

It seems a little surprising that better progress has not been made with vertical gas engines. In this part of the country we appear to have stuck to the horizontal type. The vertical engine has considerable advantages in that the crankshaft, the fly-wheel and the reciprocating parts are light and can be better balanced. The cylinders may be of moderate proportions and increased in number for the higher powers, using standard patterns so far as the details are concerned. Less floor space is occupied and much better turning effort is obtained which is necessary for successful electric installations.

Mr. George Saxon remarked that he had the opportunity some time ago of going through the large works of the Cockerill Co., Belgium and there saw in progress, and in various stages of erection, some very large gas engines which showed the wonderful progress that had been made owing to the introduction and improvements of producer gas plant, but mainly due to the utilisation of blast furnace gas. To the Société Cockerill was due the enterprise of making these very large units, and they must have had some considerable difficulty in their manufacture and bringing them to the point of perfection.

He thought makers of large gas engines in this country would also like to see the users or the Insurance Companies take up the risk of damage or breakdown, as was done on the Continent. Owing to the great heat set up, not only were elaborate cooling arrangements necessary to prevent breakage caused by undue expansion, but the parts had to be made sufficiently strong and so adjusted as to prevent these breakages and thus it had brought about in large units a very great risk indeed. Notwithstanding that, he thought makers of large gas engines had now very largely overcome the considerable difficulties which had previously been experienced.

As Mr. Bickerton had mentioned, the English (practically speaking, Lancashire), not only produced the largest number, but also the best type of engines. He was proud that Lancashire makers had maintained their reputation in that way. There was no doubt a great future for the gas engine, owing to the advantages derived from producer gas and blast furnace gas.

Mr. J. G. Walthew said that Mr. Bickerton, in presenting his Paper, had been most fair to all other gas engine makers throughout the country, but very little mention had been made of vertical gas engines. These vertical engines, had, he thought, come to stay.

The reference to governing was very meagre. The "hit and miss" system was quite good enough for certain class engines, and it had done excellently in the past, but progress generally rendered some other system of governing necessary in order to keep the gas engine at the front, at all events if it were to still further enter the electrical field and electric traction generally. If the "hit and miss" system of governing were compared with some other system, such as the throttle, or some system as described by Mr. Atkinson when pointing out some of the faults of the throttle system, it would be seen that with the latter system one could maintain all the advantages of throttle governing, and at the same time dispense with a great many of the disadvantages, one great objection being when running on light load a decreased compression was obtained; but even that was not altogether a bad thing say with single cylinders, *i.e.*, single cylinder per crank—not tandem—where the inertia forces were not very great, and no trouble was experienced from knocking; as long as no trouble was experienced from this cause, and if the economy generally was good, there was little fault to be found with the throttle system, but instead many points of advantage, especially on the score of simplicity.

Respecting gas engine crankshafts breaking, one cause of this in the past, had, he thought, been due to the irregular and violent explosions which were transmitted during one revolution, to be followed by a series of misses. This had put the crankshaft material in a far worse condition than a steady application of load would have done, such as is obtained from throttle governed engines. If a light load were being run on a throttling engine, less stress was being applied to the crankshaft the whole time, because the initial explosion forces would be lower, and would be applied with constant regularity throughout the entire operation of the engine.

The vertical gas engine, however, lent itself admirably to a great many other conditions. With the multi-cylinder engine there was a good turning moment, much better than with single cylinder engines; the floor space occupied was small. In comparison, the maximum loads were much less, owing to smaller diameter cylinders which meant light moving parts; and the ease with which the engine could be started with compressed air when there were many cylinders, was another very great point of advantage.

Regarding the system of ignition, the author had not mentioned the high tension system. With this system there were no mechanical contrivances other than a very small commutator whereby the electrical current was controlled; there was no mechanical make and break inside the cylinder, and where many cylinders had to be dealt with, and high speed of revolutions, that was a very serious point.

Turning again to the question of breakage of crankshafts; where heavy flywheels were employed, trouble was caused through excessive wear of journals and the shaft getting out of line; but with a vertical engine, with comparatively light flywheel, the wearing down was more or less equal throughout the crankshaft, and consequently the shaft was not so liable to get out of line as with a single cylinder engine with three bearings and heavy flywheel.

Mr. W. H. Cook asked if the author was correct in saying that he would sell a producer which would produce 20BHP for 1d. He thought that matter ought to be thoroughly explained.

Scotch anthracite had been mentioned in respect to the trials made; but this anthracite in his opinion was not so reliable as Welsh. Anthracite which was satisfactory for working with producer plants and gave the least trouble cost about 25/- per ton delivered Manchester, and at this price the consumptions

given in the Paper worked out to about 9HP for 1d. Had the author meant to guarantee 20BHP for 1d. in the Manchester district?

Mr. JOSEPH H. STUBBS said that as regards the reference to monopolies of patentees, there had been of course many gas engine makers who had looked with great envy on Messrs. Crossleys because they had the Otto patents.

Mention had been made of the difference in the power of the engine when using producer gas as compared with the power when using ordinary gas. He was informed that it was absolutely necessary, in order to get the same power out of an engine with producer gas, that the cylinders must be made at least 20% larger. This was a great drawback in cases where gas engines were already at work, because if there was an engine say 60BHP and a producer was afterwards fitted to it, it meant that only 48BHP could be got out of that engine.

Respecting automatic ring oilers for crankshaft bearings, he believed that it was Messrs. Andrews who originally applied these to gas engines, and which was afterwards copied by other makers. It was the best method of oiling, as some of the present arrangements were very unsatisfactory as they took in along with the oil a great quantity of dust, which was the main cause of heated bearings.

He agreed with Mr. Cook's remarks respecting 20BHP for 1d. Some gas engine makers advertised that with their up-to-date gas engines using Manchester Corporation gas at 2/- per 1000 feet electricity could be made at ½d. per unit. With power obtainable at 20BHP for 1d. the cost of electricity per unit would then come to $\frac{1}{20}$ of a penny. Is not this a very low figure?

In regard to the responsibility of users of gas engines for breakdowns, he thought that the maker of an engine or any-

thing else (if he had faith in his manufacture) ought to guarantee it and keep it in order, and not expect the user to pay for the makers' lack of information in not making engines up to requirements.

He wished to know whether it was preferable to have a separate suction plant to each engine. If there were several engines, was it necessary to have a separate plant for each, or one large plant and draw the gas from that. He was told that the gas taken from a large plant was not as good with say part of the engines stopped and part working, as it would be if there was a separate plant to each engine.

Mr. James Atkinson further remarked that it had been said respecting the breakage of crankshafts, that these shafts should be made stronger. That, however, was not the proper way to deal with the question; if there was an engine with a crankshaft and three bearings running a little out of line, and a heavy flywheel on the engine, every time the shaft was rotated, no matter how strong it was, it would deflect, and if it was too large it would be more rigid, the deflection would strain it more and it would break earlier than with lesser scantlings.

Mr. T. Rigby remarked that in the analysis of Dowson gas which was given, the nitrogen and Marsh gas seemed to him exceptionally high; the largest percentage of Marsh gas in Dowson gas he had hitherto come across had been about 1%, and it contained less than 12% hydrogen. He would like to know whether there was anything exceptional in the working of the plant, and the name of the colliery from which the anthracite was obtained.

Reference had been made to plants designed for the recovery of ammonia sulphate. On behalf of Messrs. Crossley, he had recently been experimenting in this direction, and had met

with some degree of success. The chief drawback to the Mond gas plant had been firstly its great cost, and secondly, the poor quality of the gas produced, this being thought necessary to enable the maximum quantity of sulphate of ammonia to be recovered. He, however, did not think it necessary, and the problem he had to deal with in the experiments was to make a richer quality of gas, and at the same time recover the same amount of sulphate of ammonia as a bye-product. They had now made a richer gas containing about 165 B.T.U.'s, which was about 20 or 30 B.T.U.'s more than the Mond gas plant generally gave, and this had not affected the yield of ammonia in any way, excepting that it had increased it.

This gas was recently tested at Openshaw by Mr. Rudolf Mathot, and the figures given were obtained by him.

In respect to the Horsehay gas plant, in this the principle employed was to cool the gases by surface contact, as against the principle of cooling them direct by water. This, the author had stated, was done with the idea of keeping water away from the tar so as to get a more saleable tar. He (Mr. Rigby) had found in his experiments, that when the gas was washed with water and came in direct contact, by the provision of proper settling pits, there was no difficulty in finding a good market for the tar from recovery plants of the new system mentioned, even though it came very much in contact with the water.

It had also been mentioned that the Wilson producer plant used very little water. In the Wilson principle of treating the gases atmospherically, it was necessary to put little steam through the producer, and to work with a hot fire and therefore clinker was made; the slack, if bituminous coal was being used, would contain anything from 10 to 30% of ash, and the higher the temperature the more clinker would be formed. The Wilson producer had to be cleaned once in every

24 hours owing to clinker, but the new Crossley plant could be run for weeks at a time without stopping for cleaning.

In his recent paper on gas producers, he then stated that a producer which attempted to fix the tar in the gas producer so as to obviate any further cleaning, was not worth the cost of such extra tar fixing apparatus if it did not thoroughly do it. That was the case with all producers which had so far attempted to so fix the tar. At the same time, speaking of the future, he thought that the plant which would gasify *any* fuel without discrimination was the one which would eventually replace all others. It was necessary with most of the small suction plants now being sold, and also with large suction plants, to carefully choose the fuel, anthracite costing about 25/- per ton being used; and even at that price with moderate sized engines, a great economy would be found over present steam practice, but a still greater economy would be obtained if common fuel could be used costing about 6/- If the same efficiency could be got as in the regenerative gas plants, such as the suction type, he thought that such a producer would accelerate the rate of advance of the internal combustion engine at a greater rate than it had been even by the present suction plant using anthracite.

Mr. Thomas Ashbury, in a communication, said that not having had the opportunity of speaking at the discussion on the excellent paper which had been presented, he desired to express his obligation to the author not only for the intrinsic value of the paper, but for its historical value on so modern and important a subject.

He was in agreement with the author's opinions as to the reasons why England had been so much behind the Continental makers in the development of the gas engine, and with him, hoped the cause would be removed so as not to unduly hamper or impede this country being in the front rank of progress.

It would be much appreciated if the author would express his opinion, based on his wide experience, as to the relative economical advantages gained by, say:—

A. Owners and users of gas engines who make their own suction gas on the best system in use, and adopt it to drive their gas engines (independent altogether from towns gas), compared with

B. Owners and users of gas engines who may be situated in a district that is supplied with independent gas mains constantly charged from a central station, specially erected for producing and supplying through its own mains, Mond gas, the maximum charge of which not exceeding 4d. per 1,000 feet, as registered by the consumer's meter.

C. Which system, all things considered, would be the most economical for the users of gas engines, and under what conditions either system would have an advantage.

Mr. Ashbury said he would be obliged by the author giving replies to these questions.

Mr. W. Ingham said the paper read by Mr. Rigby last year on "Power Gas Plants, etc.," already referred to by previous speakers, led to a discussion of a somewhat contentious character.

This being the Jubilee Session of the Association, it was suggested by the Council (as Mr. Bickerton said in his opening remarks) that the papers should partake more of a historical character.

The author had given a paper full of interest and useful practical information. It was of course impossible in a paper like this to mention every firm, or every individual, who has contributed, or materially assisted in bringing the gas engine to its present state of perfection.

After Mr. Rigby's paper last session, he (Mr. Ingham), in view of the remarkable economy claimed for the suction gas engine, was led to make enquiries into the possibilities of the gas engine on behalf of some friends who were contemplating putting down new plant, and he collected a considerable amount of valuable information.

One of the principal objections to the adoption of the gas engine for large powers urged by the advocates for steam was the difficulty of starting large engines.

Mr. Dugald Clerk in his work on the Gas and Oil Engine, after describing the Lanchester and Clerk starters, specially mentions a starter made by Messrs. Fielding & Platt, of Gloucester, which seems to be one of the simplest and most effective and powerful of the types referred to by Mr. Bickerton.

He (Mr. Ingham) felt sure that it must have been by an inadvertence that Mr. Bickerton in his references to the most prominent of the firms making gas engines had omitted to mention the firm of Fielding & Platt.

From 1881 to 1893, Mr. John Fielding took out some eight or nine patents, some of considerable merit, and as far back as 1882 he first introduced and patented the arrangement inside the cylinder of a "make and break" contact for igniting the charge electrically.

It was successfully applied by him on several engines at this time, and he (Mr. Ingham) had a photo of one of these engines made in 1882 (which were of the two cyle type), in which the burnt gases were expelled by a body of air entering in advance of the fresh charge, very much in the way that the two-cycle engines are worked at present. Such engines were not able to compete with the simpler and more effective four-stroke cycle.

Mr. Fielding's self-starter for large gas engines seems to have the merit of extreme simplicity, as it consists only of a small reservoir of compressed air under a pressure of about

60lbs. per square inch, with a simple valve arrangement to connect it to the engine. The air is compressed into the reservoir by the engine itself, and stored up until wanted.

Unlike other starters, it does not require the pumping or storage of explosive mixture; there is no explosion except in the engine cylinder, and no additional ignition is required beyond the usual ignition in the engine. It has the further advantage of being always ready for use as soon as the ignition tube is heated, and it has the merit of reliability, inasmuch as it has no delicate or complicated parts, and nothing subject to wear and tear, and the small reservoir of compressed air can be placed in any convenient corner of the engine house.

Respecting bituminous plants, some twelve months ago he (Mr. Ingham) was informed this firm were making a four-cycle vertical engine working with producer gas from bituminous coal without any difficulty, and they were working on the lines of getting rid of the tar in the generator itself instead of by subsequent elaborate systems of purification, and the results so far obtained, seem to show that this is the right line to adopt.

We were evidently on the eve of great changes in the economical production of power, and Mr. Bickerton's paper, apart from its historic value, he thought they would all agree, was one of the most interesting and practical of any they had had for a long time.

The whole subject was brimful of interest, and in concluding he should just like to refer to what had taken place at the meeting of the Gas Committee in the Manchester Town Council during the past week.

To encourage the use of gas for power purposes the Chairman of the Gas Committee had announced the intention of the Corporation to reduce the price of gas used for power.

This was a very proper and business-like resolution, and if gas companies throughout the country would follow this course

they might add largely to their profits, and enormously extend the use of gas, not only for engines, but for innumerable other purposes where gas might be used in the day time.

Enormous sums had to be expended initially, in laying down gas plant for lighting purposes only, because the plant must be equal to the maximum output. This was only required for a few hours during the winter evenings, and for eight or nine months of the year something like 70% or 80% of the plant was lying practically useless.

If gas was largely used for power (and it had been shown that even at the ruling prices for gas in most towns, gas would be used in the day time) the plant for its manufacture would be continually employed the year round; so that if Corporations studied their own interests and that of their consumers, they would sell at something like 50% or 60% of the charge for lighting, for all purposes, not only gas engines, but gas fires, stoves, cooking and heating, and for any number of purposes for which gas can be continually used.

Mr. Bickerton, in reply to the President's remarks, said some different system than the "hit and miss" method of governing was undoubtedly required for large size engines, and engines having more than one cylinder; but for the medium sizes, such as that described in the paper, he could conceive of no better method. It was simplicity itself. The work required of the governor was extremely small, there being no friction to overcome, as it merely selected by the position of the die whether the engine should take a charge of gas or not.

Mr. Atkinson has pointed out that Mr. Dougal Clerk first exhibited his engine at the Kilburn Show, which was held a year earlier than stated in the paper. That was undoubtedly correct: also that the Bradford firm mentioned in the paper was that of Mr. Sam Clayton, who first made and exhibited at a

public exhibition an engine working on the Otto cycle, in which the charge was ignited by a hot tube, in accordance with the arrangement patented by Mr. Watson. That Mr. Atkinson had suggested the use of a hot tube for the purpose of ignition in a gas engine much earlier, he trusted had been made plain in the paper. The idea, however, of igniting the gases in a gas engine with a hot tube or hot filament, was very old. One of the first engines with which he experimented, in 1879, was ignited with a small thimble of platinum (kept hot by an external flame) projecting from the side of the cylinder, and although it would ignite the charge, there was a considerable uncertainty about it, due to the presence in the thimble of consumed gases. Mr. Watson, in his arrangement, got over this difficulty of consumed gasses by making the tube sufficiently long so that there was a part beyond the heated part into which they were compressed. This Watson clearly shewed in his specification.

The breaking of crankshafts was probably due to all the causes that had been mentioned. If there were three bearings and one of them was lower than the other, the shaft will certainly break if allowed to continue running in that condition, but it appears to him, as pointed out, that the high bearing would immediately run hot and therefore give warning; although some shafts might have been broken through this cause, he was more inclined to agree with Mr. Onions that the absence of liberal fillets, where changes of diameter took place, and where the shaft met the web of the crank, was a matter of more serious importance. The bulk of crankshafts broke in this particular place. Mr. Atkinson had pointed out that with two wheels and two bearings only, the shafts were not so liable to break; he was inclined to think that this was not so much due to the absence of the third bearing as to the fact that the force exerted was distributed in two directions and through two necks of the shaft instead of one, and therefore the strain was not so

severe. It was highly important that a large margin of strength should be allowed in the construction of a crankshaft, and also that the fly-wheel keys should be ample. Many shafts had been broken through the neglect of the attendant in allowing the engine to work with slack keys.

He quite agreed with Mr. Atkinson's remarks on governing. The stratification governor for engines with more than one cylinder and long strokes had many advantages, but he thought that the reason why the Continental makers were having more success with this method than Mr. Frank Crossley had, was not so much due to the higher compression as to the fact that electric ignition was employed in place of the old flame, or hot tube ignition. The Clerk starter might be more effective than the one mentioned in the paper, but it was more expensive to construct, more work was required from the attendant, and put more strain on the engine, The ignition took place at atmospheric pressure, and therefore any slack in the general bearings was not taken up previous to ignition. With the starter mentioned in the paper this was done due to the compression put into the cylinder by the hand pump, which was as much as possible without moving the fly-wheel, and therefore the start was made much quieter than with the Clerk starter. Mr. Atkinson had called attention to the thermal efficiencies of a Crossley engine given in the Appendix of Mr. Rigby's recent paper on gas producers. Those efficiencies were the results of private tests made by Mr. Atkinson and Professor Burstall. He was not puttiug the efficiencies given in this paper as the very best that could be got from a National engine. The engines tested by the Research Committee of the Civil Engineers were three ordinary commercial engines, similar to those which were going out from the works every day. The water cooling arrangements mentioned in the paper were those in ordinary use, viz: water jacketing of the cylinder and combustion

chamber, and water circulating through the valves and pistons, as adopted by many makers. He was not referring, as Mr. Atkinson suggested, to the arrangement which he understood Messrs. Crossley Bros. had recently adopted for cooling the charges in gas engines by injecting water into the cylinder; he had purposly avoided mentioning anything of so modern a character, and he did not like to pass an opinion or give any information on an arrangement of that kind until he had seen something more of it.

Mr. Onions has drawn attention to the importance of liberal fillets being provided in the crankshafts, and with this he quite agreed, as already stated in answer to Mr. Atkinson's remarks. He could not agree with him, however, with reference to the necessity of some means for varying the time of ignition whilst the engine was at work, and the suggestion that this was necessary under varying loads and gas mixture. He could understand the necessity for a variable ignition on a motor-car engine where the speed was changed frequently and also the mixture, but in the ordinary workshop engine the speed of rotation was fixed and the mixture and quality of gas were arranged when the engine was started. Some simple arrangement for delaying the point of ignition during the starting of the engine, and when it was moving slowly was undoubtedly an advantage, but if the engine had been got to work he should look upon any method by which the time of ignition could be altered as a source of weakness, as it was impossible to determine the exact point of ignition unless an indicator was on the engine. Therefore in the engine described and those which are built by his firm, the point of ignition was fixed, with the exception that an arrangement was employed for delaying the ignition during the period of starting. Mr. Onions appeared to be in favour of the inverted verticle type of gas engine, and expressed surprise that so little progress had been

made with them. He quite agreed with him that there were many points of advantage in engines of this type over the horizontal, but up to the present the only firm who have built them in numbers were the Westinghouse Co., and he regretted that he had been unable to get any information from them.

Mr. J. G. Walthew mentioned the vertical engine as one which he considers has come to stay, and he did not think there was any doubt about it. Mr. Walthew appeared to be very hard on the "hit and miss" system of governing, and suggested that it contributed, to some extent, to the breaking of crankshafts. There was no doubt that this system of governing did tend to put the maximum strain on a crankshaft as the indicating card, after a miss generally attained the highest initial pressure, due to the absence of burnt gasses and the presence of pure air. It would appear therefore that there were good grounds for Mr. Walthew's suggestion. Mr. Walthew favoured the high tension system of electric ignition when a number of cylinders are employed with a high speed of rotation: on the other hand he found that some trouble was experienced with the tremblers on the coil and also the battery, so that for a single cylinder engine, as described in the paper, the low tension system with its simplicity and certainity of action was preferable. Mr. W. H. Cook asked if 20 BHP for 1d. could be guaranteed: most certainly "yes" in many localities, almost anywhere in Scotland where the Scotch anthracite could be obtained at about 10/- per ton. Mr. Cook was quite wrong in suggesting that there was any trouble in using this anthracite, the trials referred to in the paper conducted at Glasgow last year were sufficient proof of this. Since those trials one or two important tests had been made by independent engineers on the Dowson gas plant and National engine, using Scotch anthracite, and the result had been better than that shewn by the trials at Glasgow.

Mr. Stubbs thought that monopolies were good things for those who had got them: with this opinion they all agreed, but he was looking at it from the point of what would be the greatest good for the greatest number, and he was still inclined to think that a patent law which allowed an exclusive monopoly was rather a mistake for the trade in general. Mr. Stubbs suggests that ½d. per unit for generating electricity was too low a price. The National Co. had installed many installations in Scotland where 12 units for 1d. are produced, for fuel cost, and this works out at much less than ½d. per unit after allowing for all charges. The estimate by a speaker of 3% of crankshaft breakages, was to his mind, altogether too excessive. He should say ·3 would be nearer the mark, as breakages were almost entirely confined to medium and large sized engines and rarely occurred in engines under 20 BHP. The balancing of gas engines, as mentioned, was certainly deserving of more attention than it usually obtains.

Mr. Rigby thought that the analysis, given in the paper, of Dowson gas was questionable; it was, however, a copy of that given in Mr. Bryan Donkin's book, and was, he understood, what was communicated to him from independent source.

Mr. Thomas Ashbury asked as to the relative economy in supplying a gas engine from its own suction plant as against buying Mond gas from the mains at 4d. per 1,000 feet. The size of the engine and the character of the work for which it was employed, viz., whether intermittent or continuous, would naturally have an important bearing on the answer to this question. He should say generally for engines below 30 HP it would be preferable to purchase the gas from the main, either Mond gas at 4d. per 1,000 feet, or Town's gas at 1/2 per 1,000 feet; but for engines over 30 HP, and running continuously, it would be better to have a suction plant installed. If, however, these engines were not running continuously, it might be

advisable to take the gas from the mains even for considerable larger powers than 30 HP.

Mr. Ingham had called attention to the difficulty in starting large gas engines, and said that this was one of the principal objections to their universal adoption. There was no doubt that a good deal of nervousness was felt by the general engineer as to the certainty of being always able to start a gas engine, and he must confess that there was just ground for some nervousness. This condition of things, however, was largely due to false economy on the part of the purchaser. If a compressed air starting arrangement was installed, regardless of the extra cost, a gas engine could be started with the same amount of certainty as a steam engine. Mr. Ingham mentioned the Fielding & Platt starting arrangement, and reminded him that no mention had been made of Mr. Fielding's work in the paper. He regretted that this was the case, as there were few earlier workers on gas engines, or more earnest workers, in connection with them than Mr. Fielding. It was only possible in a paper of this kind to include a small fraction of the work of the numerous toilers in the developement of a new industry.